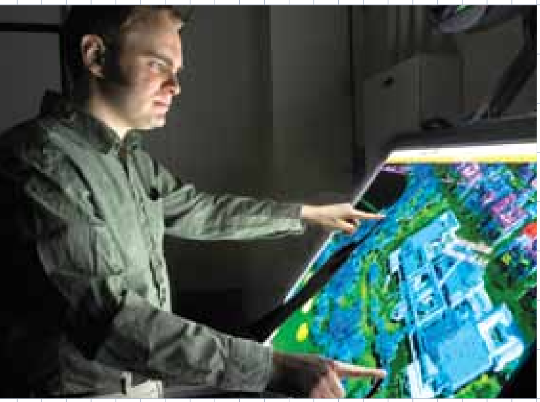
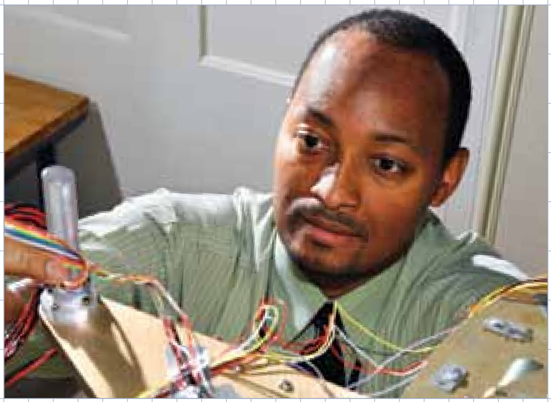


ANNUAL REPORT

MIT LINCOLN LABORATORY

TECHNOLOGY IN SUPPORT OF NATIONAL SECURITY

2010

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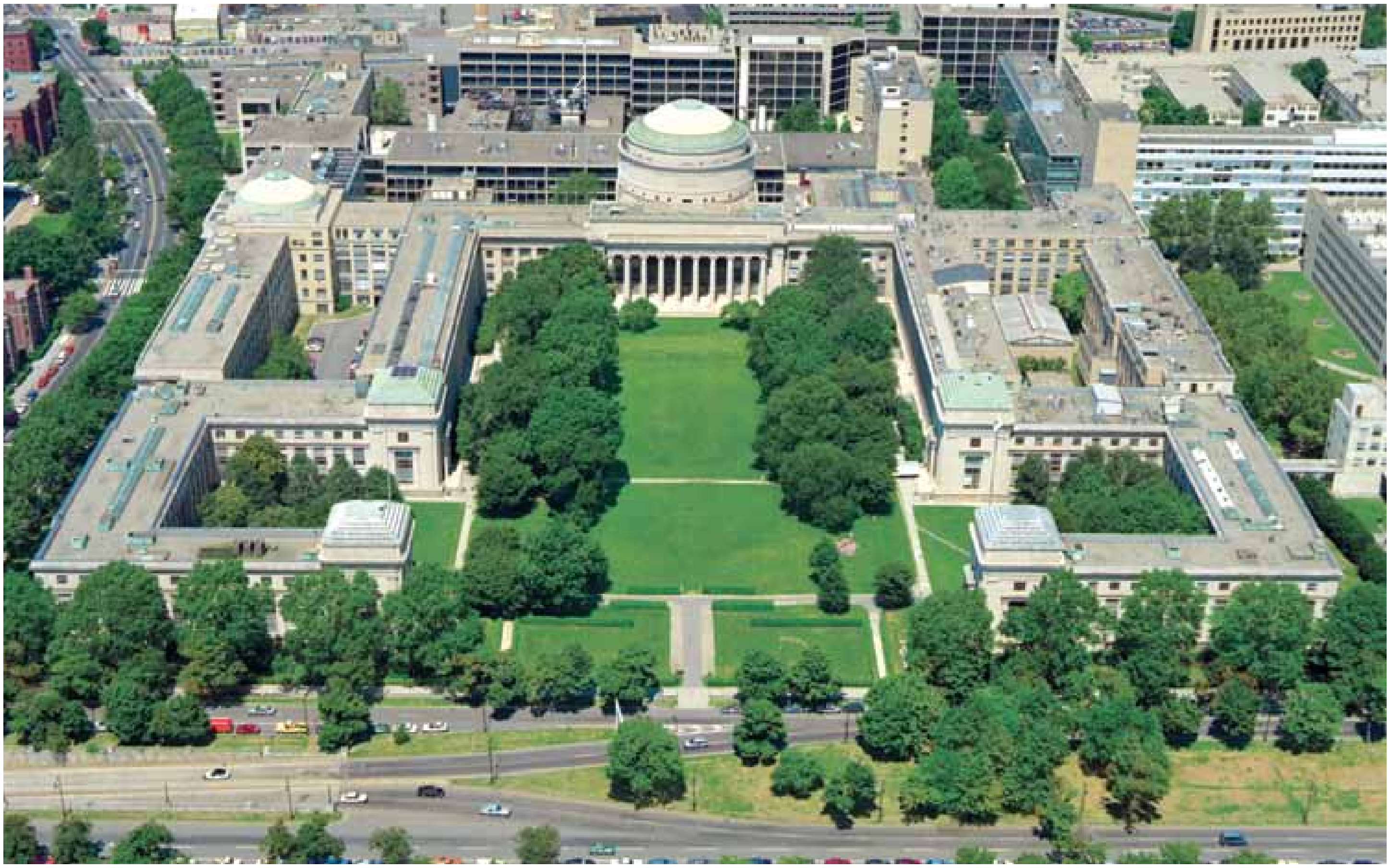

Massachusetts Institute of Technology

MIT Lincoln Laboratory

MIT LINCOLN LABORATORY 2010

MISSION

Technology in Support of National Security

MIT Lincoln Laboratory employs some of the nation's best technical talent to support system and technology development for national security needs. Principal core competencies are sensors, information extraction (signal processing and embedded computing), communications, and integrated sensing and decision support. Nearly all of the Lincoln Laboratory efforts are housed at its campus on Hanscom Air Force Base in Massachusetts.

MIT Lincoln Laboratory is designated a Department of Defense (DoD) Federally Funded Research and Development Center (FFRDC) and a DoD Research and Development Laboratory. The Laboratory conducts research and development pertinent to national defense on behalf of the military Services, the Office of the Secretary of Defense, the intelligence community, and other government agencies. Projects undertaken by Lincoln Laboratory focus on the development and prototyping of new technologies and capabilities to meet government needs that cannot be met as effectively by the government's existing in-house or contractor resources. Program activities extend from fundamental investigations through design and field testing of prototype systems using new technologies. A strong emphasis is placed on the transition of systems and technology to the private sector. Lincoln Laboratory has been in existence for 59 years. On its 25th and 50th anniversaries, the Laboratory received the Secretary of Defense Medal for Outstanding Public Service in recognition of its distinguished technical innovation and scientific discoveries.

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Letter from the Director

For nearly sixty years, MIT Lincoln Laboratory has fulfilled its mission of providing advanced technology for our national security by anticipating the nation's challenges and evolving its mission areas and programs to meet those emerging challenges. This year, the Laboratory restructured three divisions to focus research and development in areas that are increasingly important to the nation: homeland protection; cyber security; and intelligence, surveillance, and reconnaissance (ISR) systems. The Laboratory's new Homeland Protection and Air Traffic Control Division will concentrate on developing and expanding the Laboratory's work on chemical and biological defense, border security, and the safety of the National Airspace System. The new ISR and Tactical Systems Division's emphasis will be on developing systems for surface and undersea ISR, counterterrorism, and tactical operations. The restructured Communication Systems and Cyber Security Division will continue to enhance the capabilities of the nation's defense communication systems and will strengthen programs to protect the nation's networks and critical infrastructure. This annual report will highlight some of the Laboratory's new work in these areas.

The Laboratory is continuing work on its large-scale hardware and software programs, such as the Haystack Ultrawideband Satellite Imaging Radar, the Lunar Laser Communications Demonstration, and the Missile Alternative Range Target Instrument. To support the development and integration of such systems, the Engineering Division began investing in new equipment to improve hardware fabrication and integration, and to add new capabilities in printed circuit board assembly, precision machining, and prototyping. In addition, the Laboratory is in the midst of a three-year recapitalization of the Microelectronics Laboratory to enable improved wafer processing and advanced packaging.

The Laboratory's many accomplishments this year included milestones in the following areas:

- The Extended Space Sensors Architecture Advanced Concept Technology Demonstration successfully demonstrated the networking of space and missile defense sensors in real time.

- The Laboratory demonstrated a laser communications system that mitigates signal fading caused by atmospheric turbulence. Error-free data transfer from an aircraft at 12 kft to a ground station was achieved.

- The development of net-centric architectures that facilitate use of networked resources is progressing. The goal is to transition these to military net-centric operations.

- The Laboratory demonstrated laser beam combining that achieved more than 45-watt coherent output from an array of six 20-diode modules. This is a significant step toward producing an efficient, high-power laser source.

- A prototype weather system providing 8-hour storm forecasts over the continental United States blends technology from the Corridor Integrated Weather System with numerical weather prediction models and is being evaluated at operational air traffic control facilities.

- The Laboratory has made significant advances in secure, cryptographic key transmission by using superconducting, single-photon-counting niobium nitride nanowire detector arrays.

- The digital focal-plane array, a novel infrared detector array, demonstrated panoramic multiwaveband and infrared imaging for persistent surveillance. This technology has the potential to dramatically improve infrared surveillance and missile seekers.

This year, five Lincoln Laboratory technologies were recipients of *R&D Magazine*'s annual R&D 100 Awards, which recognize the 100 most significant technological advances introduced during the previous year. The digital focal-plane array, miniaturized radio-frequency four-channel receiver, Runway Status Lights system, Geiger-mode avalanche photodiode array, and superconducting nanowire single-photon detector array were honored.

Collaborations with MIT campus continue to grow, leveraging the strengths of researchers at both the Laboratory and campus. The first annual MIT Lincoln Laboratory Best Invention Award went to a Laboratory/campus team for the Multi-element Optical Detectors with Sub-wavelength Gaps. The Technology Office is encouraging innovation and experimentation through a number of avenues, including the first annual Technology Office Challenge, a competition to find unique solutions to a situational awareness scenario.

In the aftermath of the earthquake in Haiti, the Laboratory assisted with U.S. military relief efforts. The Airborne Ladar Imaging Research Testbed (ALIRT) system was deployed to provide much needed three-dimensional imaging of the damaged regions of Haiti, and members of the Communication Systems and Cyber Security Division developed tools to assess the effectiveness of relief operations.

The Lincoln Laboratory Community Outreach program is thriving. Science on Saturday programs for local K–12 education have continued, and the Laboratory's robotics league now mentors eight student teams for local, state, and national competitions. In partnership with the MIT Office of Engineering Outreach Programs, the Laboratory is participating in four new programs that encourage middle- and high-school students to consider careers in science, technology, engineering, and math. Laboratory employees continue to support community service, adding the Alzheimer's Walk, Coats for Kids, and other programs to our list of charitable projects.

We encourage you to review the 2010 Annual Report for information about our current research and development efforts, technology innovations, recent awards, and outreach activities. We are looking forward to the future as we continue to focus on technical excellence, innovation, and integrity.

Sincerely,

Eric D. Evans

Eric D. Evans
Director

Lincoln Laboratory Strategic Directions

Strategic directions for Lincoln Laboratory are based on a Director's Office and senior management update of the Laboratory's strategic plan and a review of national-level studies, such as the National Defense Strategy, the Quadrennial Defense Review, and recent Defense Science Board recommendations.

Nine Directions

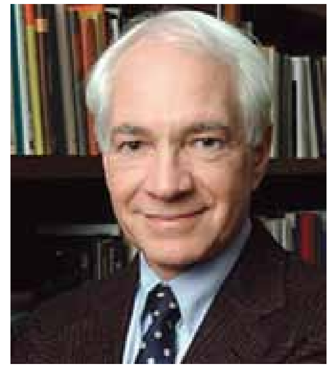
- Identify new mission areas, based on current and emerging national security needs
- Strengthen and evolve the current Laboratory mission areas
- Strengthen the core technology programs
- Increase MIT campus/Lincoln Laboratory collaboration
- Strengthen technology transfer to acquisition and user communities
- Increase outside connectivity and communications
- Improve Laboratory diversity and inclusion
- Expand community outreach and education
- Continue improving Laboratory engineering services, administration, and infrastructure

MIT and Lincoln Laboratory Leaders

Massachusetts Institute of Technology

Dr. Susan Hockfield
President

Dr. L. Rafael Reif
Provost



Dr. Claude R. Canizares
Vice President for Research and Associate Provost

MIT Lincoln Laboratory

Dr. Eric D. Evans
Director

Dr. Marc D. Bernstein
Associate Director

Mr. Anthony P. Sharon
Assistant Director—Operations

Leadership Changes at MIT Lincoln Laboratory

Division Realignment

In March 2010, Lincoln Laboratory realigned two divisions to consolidate programs in complementary mission areas and to refocus on emerging priorities of the Department of Defense and the intelligence community. Homeland Protection and Tactical Systems was reorganized as the Homeland Protection and Air Traffic Control Division, and Intelligence, Surveillance, and Reconnaissance (ISR) Systems and Technology became the ISR and Tactical Systems Division.

Dr. Robert T-I. Shin

Robert T-I. Shin

Division Head, ISR and Tactical Systems

Dr. Robert T-I. Shin transferred from the Homeland Protection and Tactical Systems Division to lead the ISR and Tactical Systems Division, which has become the center for programs in surface surveillance and undersea ISR, tactical systems, air vehicle survivability, and counterterrorism and counterinsurgency. Dr. Shin oversees the development of prototypes in radio-frequency, electro-optical, infrared, and acoustic systems, sensor algorithms, adaptive array processing, embedded computing, and integrated sensing and decision support.

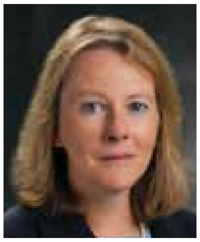
Dr. Israel Soibelman

Israel Soibelman

Division Head, Homeland Protection and Air Traffic Control

Dr. Israel Soibelman leads the Homeland Protection and Air Traffic Control Division, which has responsibility for programs in homeland air defense, chemical and biological defense, homeland security, and air traffic control. Dr. Soibelman oversees the development of systems for detection and warning of chemical or biological attacks, for defense of the U.S. air space and borders, and for protection of the U.S. critical infrastructure. In addition, the division is supporting the Federal Aviation Administration's ongoing efforts to improve air safety and air traffic management.

New Leadership

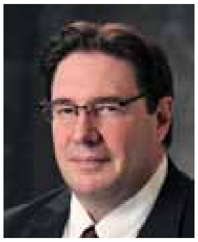


Ms. Patricia O'Riordan

Patricia O'Riordan

Department Head, Financial Services

Ms. Patricia O'Riordan was appointed Head of the Financial Services Department in September 2010. As the manager of financial operations supporting Lincoln Laboratory's research and development, she is responsible for corporate financial planning and reporting, accounting operations, property management, and travel services.



Mr. J. Michael Menadue

J. Michael Menadue

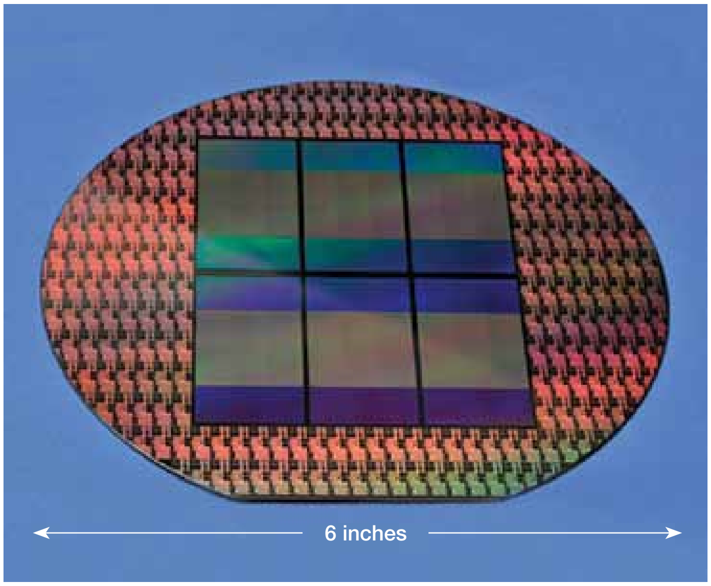
Manager, Capital Projects Office

Mr. J. Michael Menadue joined Lincoln Laboratory in July 2010 to lead the newly formed Capital Projects Office, which will address the capital planning, programming, and execution of the Laboratory's facility modernization program. He will draw on more than 24 years of experience in planning, designing, and constructing facilities for healthcare, biotechnology, and telecommunications industries to implement the phases of the modernization effort.

2010 Technology Developments

The Technology Office is responsible for developing Lincoln Laboratory's long-term technology strategy and for establishing and growing strategic technical relationships with the Defense Advanced Research Projects Agency, Office of Naval Research, Army Research Office, Air Force Research Laboratory, and other DoD and federal organizations. The office promotes collaborative research efforts with MIT and other academic research institutions in order to link novel research concepts with current and future Laboratory missions. Working closely with senior management and the divisions, the office drives the Laboratory's overall strategic and technical direction.

In the past year, the Technology Office extended the Laboratory's technology position in advanced electronics, biological-chemical sensing, photonics and single-photon communications, counter-terrorism technologies, net-centric operations, decision support, and intelligence, surveillance, and reconnaissance (ISR) sensing. New technology thrusts include biosciences, quantum information sciences, autonomous platforms, defensive cyberwarfare technologies, and energy technologies. Prior technology investments have matured into system concepts and have been transitioned to a broad sponsor and user base.



Nine 3k × 3k orthogonal-transfer charge-coupled detector (OTCCD) array focal planes fabricated on a six-inch silicon wafer. The OTCCD design can be used to minimize image blurring caused by camera motion or atmospheric turbulence. The OTCCD focal planes were fabricated using a stitched, 248 nm stepper-based process that allows high-resolution patterning to realize image pixels with submicron dimensions. A reduction in pixel dimensions leads to larger focal-plane arrays.

The Technology Office promotes collaborative research efforts with MIT and other academic research institutions in order to link novel research concepts with current and future Laboratory missions.

The Technology Office launched a range of seedling efforts throughout the year to encourage technology-driven innovations, often using university-based research as a starting point. Examples of these seedlings are projects on developing virus-built, lithium ion rechargeable batteries for payloads on unmanned aerial vehicles, developing multiferroic materials for microwave components, and building collaborative mobile robots that can navigate interior spaces.

The Laboratory's technology investments have enabled a set of new mission concept demonstrations in the homeland protection, net-centric operations, and counterterrorism and counterinsurgency areas. These projects integrate and validate advanced technology concepts through field tests and end-to-end demonstrations.

2010 Notable Achievements

- An ultrahigh-resolution, imaging laser radar having a bandwidth of 100 GHz was demonstrated successfully and is expected to find application to robotic vision.

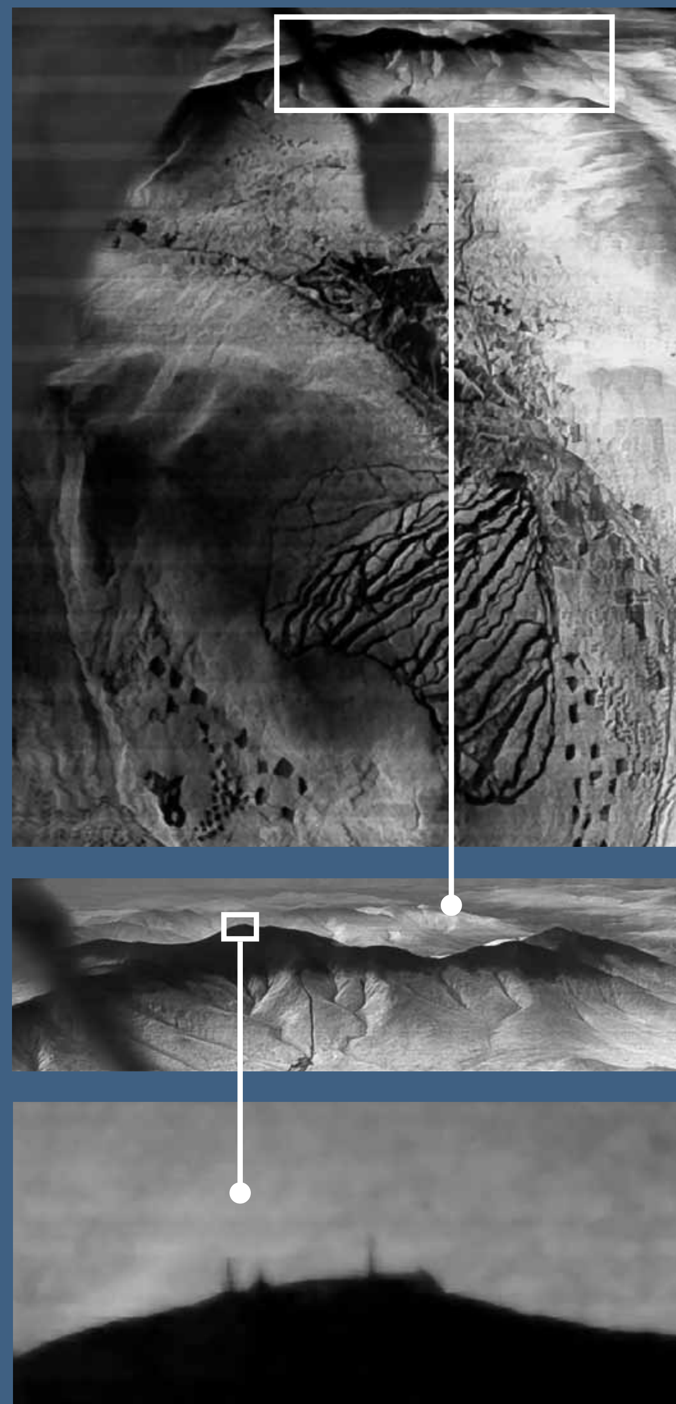
- The digital focal-plane array silicon (Si) readout integrated circuit was used with several photodetector array materials. These materials included HgCdTe, InGaAs, and quantum well infrared photodetectors. The resulting focal planes had a broad spectral range, including the short-wave, mid-wave, and long-wave infrared bands. This Si readout integrated circuit demonstrated improved performance through greater sensitivity and a larger dynamic range. The very high frame rate of an infrared imager employing a digital focal-plane array was demonstrated through stroboscopic infrared imaging of a bullet fired from a handgun. (For more on the digital focal-plane array, see p. 7.)

- The initial demonstration of an airborne multiple-input/multiple-output (MIMO) moving target indicator (MTI) radar took place in August 2009. Utilizing unique waveforms and antennas, the

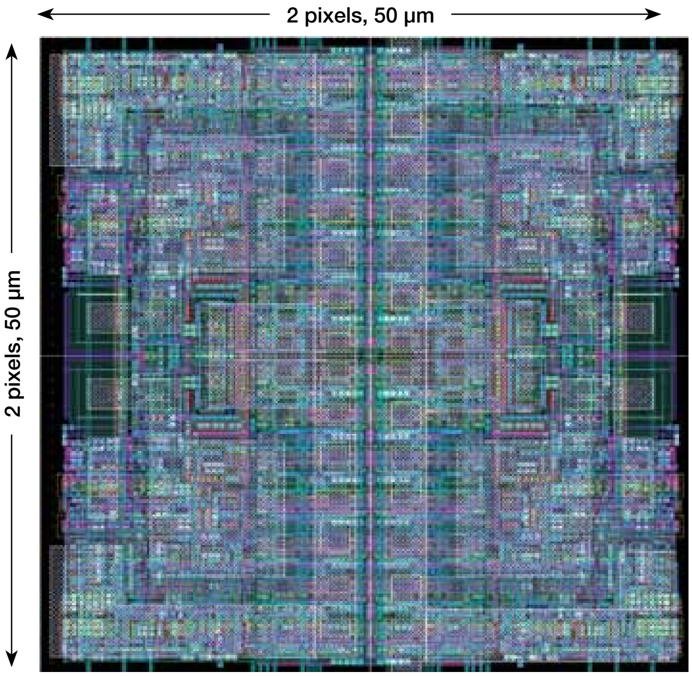
Digital Focal-Plane Array

The digital focal-plane array features a unique Lincoln Laboratory–developed silicon readout integrated circuit bonded to a commercially available long-wave infrared focal-plane array. It has been successfully demonstrated in an airborne, scanning camera system that produces unprecedented, high-resolution, infrared panoramic images. This readout technology, which significantly improves the capabilities of detectors used in wide-area imaging and surveillance applications, is being transferred to several government agencies.

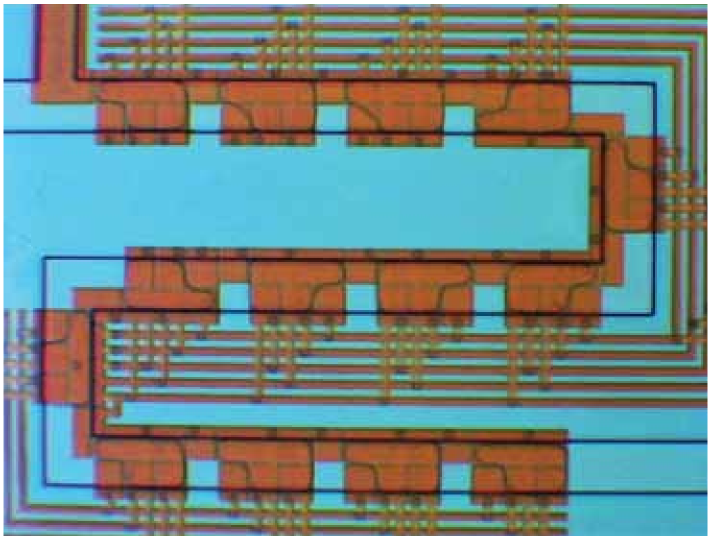
Aerial, winter night, infrared image of downtown Boston collected by a camera using the digital focal-plane array. The inset image of the Massachusetts State House partially illustrates the detail present in the image. Infrared image resolution is less than 1 meter, and the image quality is better than a high-definition television image.



Aerial, winter morning, infrared image of Mount Washington, New Hampshire. The size of the large image is approximately 200 Mpixels. This infrared image has about 10 times the information of a high-definition television image. The image insets culminate with the silhouette of the Mount Washington Observatory at the summit of Mount Washington.



Microphotograph of a 4-pixel region that is part of a larger 256 × 256 silicon readout integrated circuit of a Geiger-mode avalanche photodiode detector array. The microphotograph illustrates the level of integrated circuit complexity behind each 25 μm × 25 μm avalanche photodiode site. Each of the more than 65,000 photodiodes has an arming and active quenching circuit, pulse discriminator and latching circuits, and a 7-bit digital counter and digital readout circuit. Geiger-mode avalanche photodiode arrays are used in photon-counting laser radar and optical communications receivers.



Design, construction, and test were accomplished for several microfluidic components, including multistage oil and water pumps, rotary oil pumps, droplet generators, and valves. The above microphotograph shows a high-pressure, 14-stage, electrically operated, microfluidic oil pump. The oil pump can precisely deliver picoliters of a solution at a head pressure of 50 kPa. The microfluidic pump occupies an area of approximately 1.7 mm^2. Microfluidics holds the promise of chip-scale chemistry and biology laboratories ("labs on a chip") that can be directly coupled to electronics to allow in-field chemistry and biology measurements.

airborne MIMO MTI radar promises to significantly improve the performance of airborne ISR. Accurate geolocation of targets with minimum velocities of less than 1 m/sec was demonstrated.

- A new world record in quantum key distribution was achieved when a quantum key was transmitted at a rate of 1.85 Mbits/sec over 100 km of optical fiber, a rate 100 times greater than previously possible across that fiber length. This achievement was enabled by the development of the superconducting, single-photon-counting, niobium nitride (NbN) detector array, the world's fastest, most efficient single-photon detector operating at optical communications wavelengths. MIT received a patent on the nanowire NbN detector array in December 2009.

- A high-performance, low-power, miniature radio-frequency (RF) receiver that uses RF integrated circuits developed at Lincoln Laboratory demonstrated a 1 Hz tuning resolution over a band from 50 MHz to 3600 MHz with a spur-free dynamic range (SFDR) greater than 96 dB. By combining a commercially available, 0.18 mm silicon-germanium process with novel and robust circuit design techniques, the miniature RF receiver overcomes the limitations of other silicon processes, such as a low-breakdown-voltage constraint. The end result is performance superior to commercial products: an SFDR between 10 and 100 times better, a power dissipation that is 3 to 10 times less, and a size that is 10 to 20 times smaller.

- Key elements of a special-purpose, machine architecture designed to speed solutions of graph problems have been defined. This hardware design has been strongly influenced by graph processing algorithms. Graph processors are expected to find application in problems associated with defining social networks.

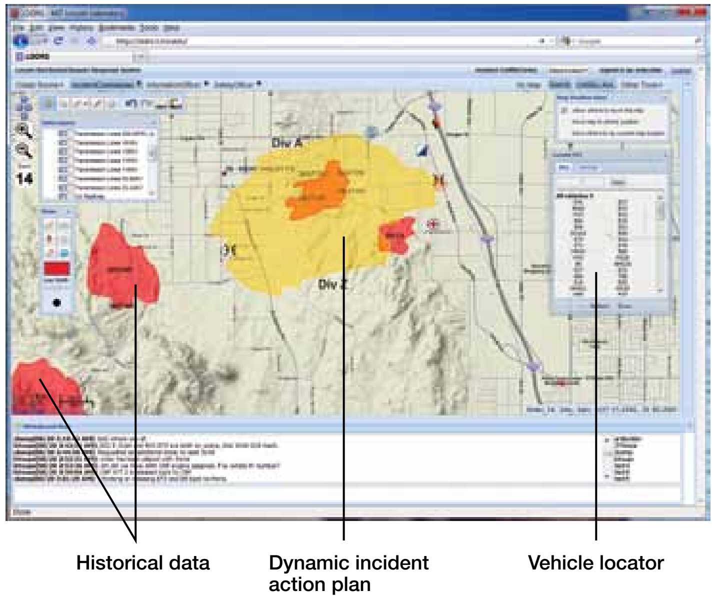
- Research into using photodissociation followed by laser-induced fluorescence to remotely detect trace amounts of explosives on objects yielded important results in fluorescence measurements on several explosive materials. Work continues on optimizing future system performance.

Lincoln Distributed Disaster Response System

A Lincoln Laboratory team, building on expertise in sensors and architectures, developed and demonstrated the Lincoln Distributed Disaster Response System (LDDRS). The initial design of the system resulted from a reconstruction and analysis of a major fire in California. Through interviews with emergency-response operators and analysis of archived radio communications, reports, incident maps, and ground and aerial imagery, the Laboratory team developed a picture of the challenges inherent in fighting a large-scale wildland fire, and more generally, in conducting a large-scale disaster response.

The system enabled information from airborne platforms, distributed weather stations, GPS-enabled devices, and other sources to be shared by responders at the emergency command centers and those equipped with ruggedized laptops at the front lines. Responders and the command centers were connected over the network and gained access to the system via a Web-based graphical interface, enabling responders from all agencies to collaborate, regardless of computer hardware or software.

The demonstration of the LDDRS this past summer tested the technical performance of the system and assessed the impact of new technologies. The demonstration consisted of scenarios representative of diverse fire response activities and involved 40 role players, all professional responders. The system successfully enabled personnel to develop and maintain real-time shared situational awareness during response operations.



A screenshot from the Lincoln Distributed Disaster Response System illustrates situational awareness tools that include geographical displays overlaid with measured vehicle locations and historical data of past fires.

The team involved in the demonstration of the Lincoln Distributed Disaster Response System tested the system in a set of scenarios, including initial response, evacuation planning and coordination, real-time flight tasking, and a search-and-rescue mission.

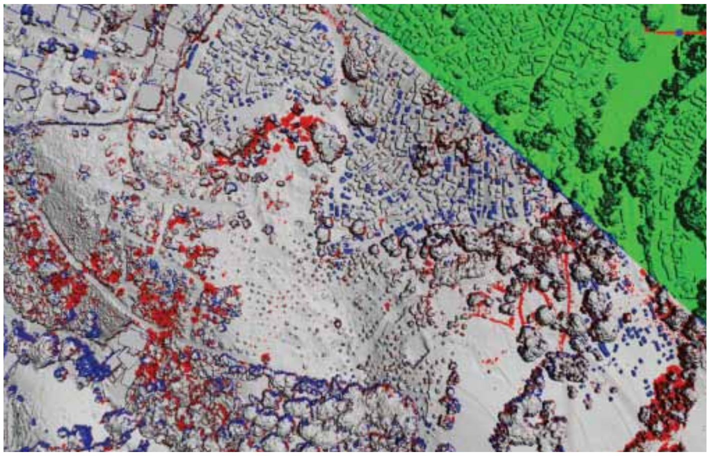
Haiti Relief Efforts

Researchers from Lincoln Laboratory helped with the U.S. military's support to earthquake disaster-relief operations in Haiti by applying their decision support expertise and the Laboratory's advanced imaging technology to provide essential information to relief agencies.

Marc Zissman, third from left, of Lincoln Laboratory has been helping USSOUTHCOM with the performance assessment of the military's disaster-relief operations. The group here is part of the team of military and relief agency personnel Dr. Zissman has been working with in Haiti.

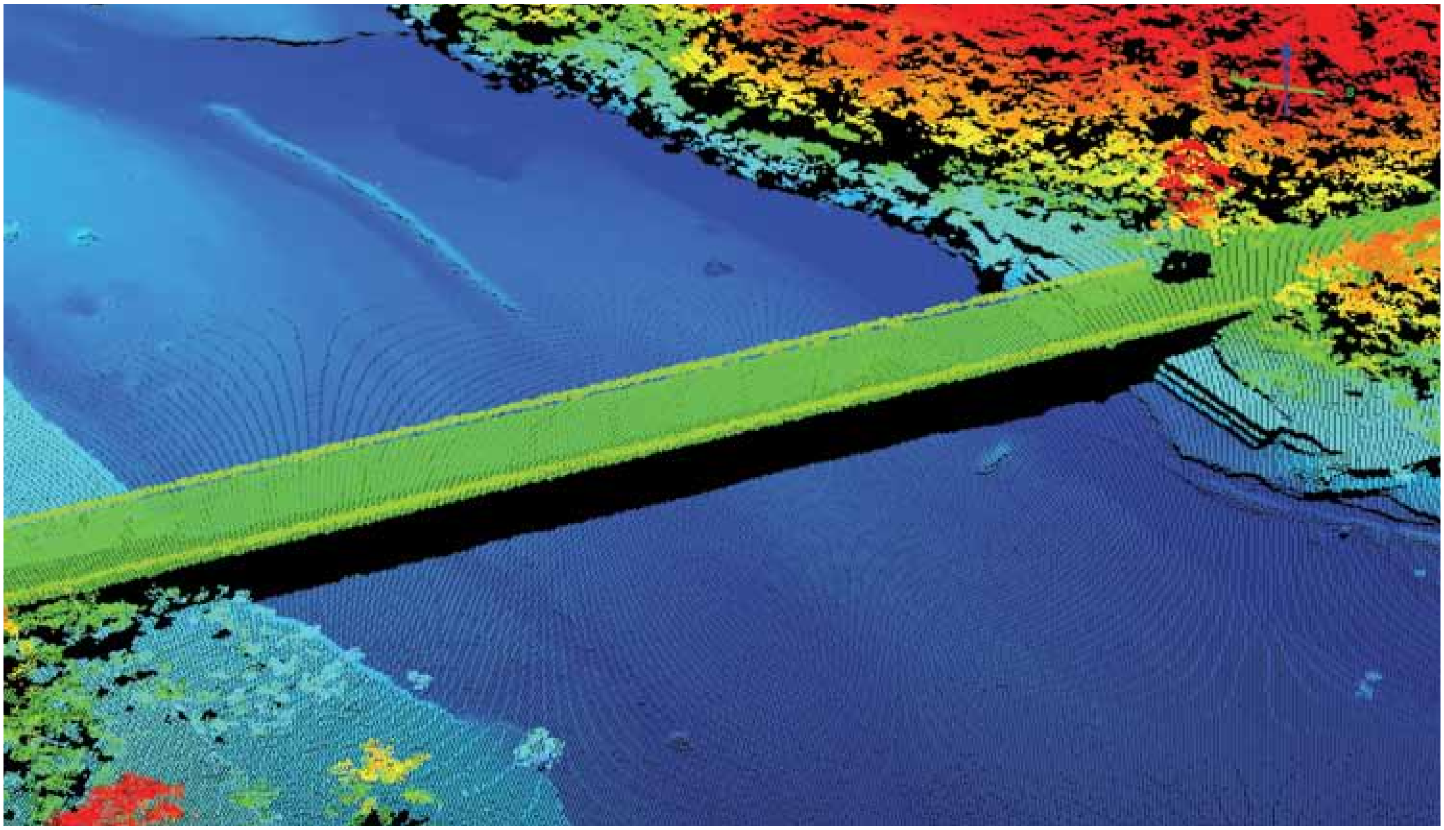
Staff from the Communication Systems and Cyber Security and the Homeland Protection and Air Traffic Control divisions assisted with the design and implementation of an assessment of the effectiveness of the Joint Task Force–Haiti relief operations. A secondary goal for this data analysis work was to leave a legacy of information that could be useful to organizations that will be doing long-term humanitarian and rebuilding work in Haiti.

Lincoln Laboratory's Airborne Ladar Imaging Research Testbed (ALIRT) system was deployed to investigate the ability of three-dimensional (3D) ladar imagery to support military efforts in Haiti. The ALIRT system, developed by the Laboratory to assess the ability of avalanche photodiode arrays to produce high-quality 3D imagery, covers a wider area than available commercial systems cover. ALIRT data collections were enabled by staff members from the Intelligence, Surveillance, and Reconnaissance and Tactical Systems Division.

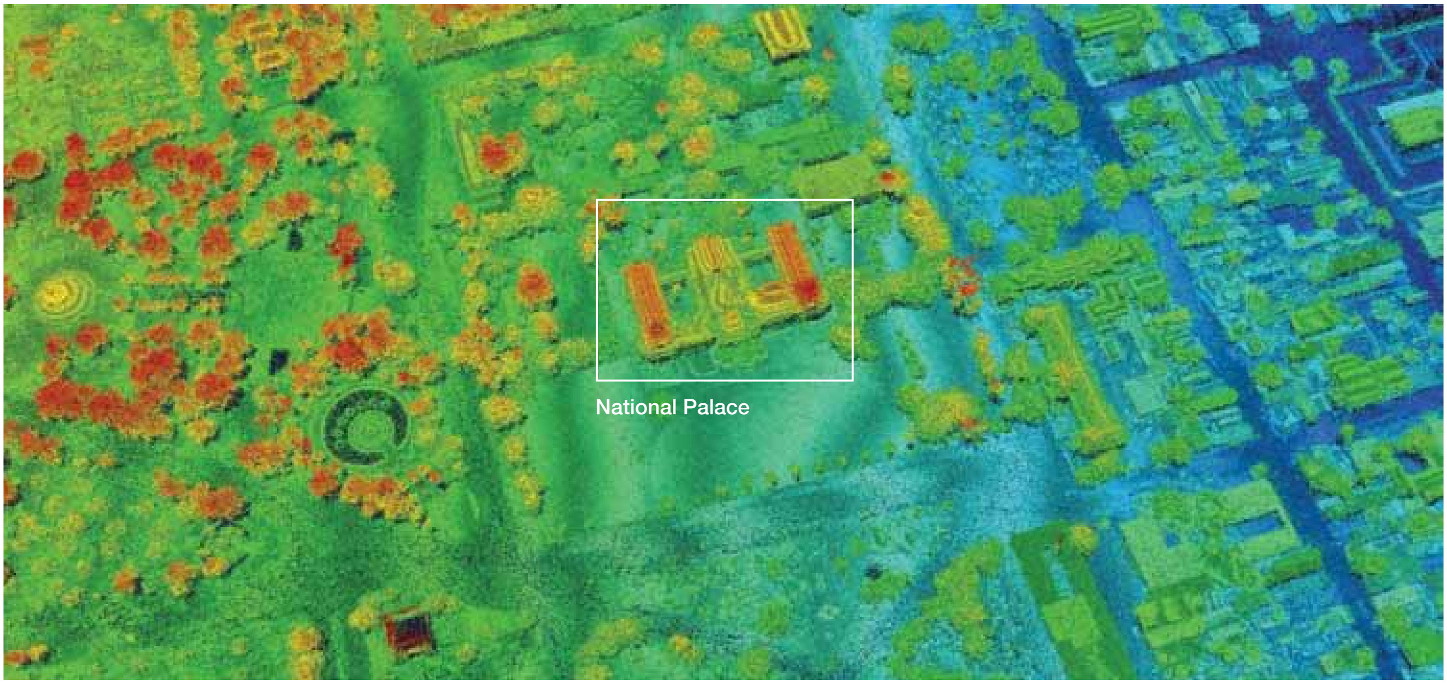


By comparing nighttime imaging of a suburb of Port-au-Prince, the military can determine activity in the area, such as an increase in the number of tents and other structures or an increase in tree cutting. Such comparisons help predict population locations, activity, and population movement. The blue areas denote objects imaged on the night of January 26, and red areas mark objects that departed the area since a January 22 data collection.

The ALIRT imagery was used to determine the migration of displaced persons, location of acceptable helicopter landing zones, trafficability of roads and bridges, and a 3D terrain base for future operations. ALIRT provided nightly volumetric change detection of the United Nations' Distribution Sites and IDP (internally displaced persons) camps in the Port-au-Prince area. The imagery data, processed by Lincoln Laboratory and team members from a number of other organizations, were delivered to the military for exploitation and dissemination to commanders to assist in making aid-distribution decisions and performing damage assessment.



This 3D image provided by the Lincoln Laboratory ALIRT system showed the trafficability of the bridge. The colors indicate the relative heights of the terrain and structures being imaged; the spectrum shades from red at the highest height through orange, yellow, green, aqua, and finally blue at the low end. The unobstructed green span of the bridge indicates its trafficability; the vehicle (black object) beginning its route will face no obstacles as it crosses the river.



This quick-look image provided by the Lincoln Laboratory ALIRT system shows the National Palace and surrounding area after the earthquake. The color code indicates the relative heights of the terrain and structures being imaged. In the center of the ALIRT image, the palace is imaged with its highest points being the (red) wings of the building; before the earthquake, a dome graced the central section of the palace and would have been the highest, thus red, imaged point of the structure.

Installation of the New Haystack Antenna

The Haystack radar facility, a component of the Lincoln Space Surveillance Complex in Westford, Massachusetts, was first developed by MIT Lincoln Laboratory in the 1960s as a step in the technological evolution of high-performance microwave systems. The X-band Haystack Long Range Imaging Radar (LRIR) was developed in 1978 to enable inverse synthetic aperture radar imaging of satellites out to geosynchronous altitudes.

Now, Lincoln Laboratory is developing the Haystack Ultrawideband Satellite Imaging Radar (HUSIR). HUSIR will operate in the 92 GHz to 100 GHz frequency band. To achieve efficient operation at the 3 mm wavelength, the 37 m Haystack antenna needed to be replaced with a new dish with 100 µm surface tolerance. With its 8 GHz bandwidth, HUSIR will be capable of much better image resolution on near-Earth satellites than LRIR. Haystack's X-band capability to image deep-space satellites will be preserved.

Capability	Haystack before upgrade	After HUSIR upgrade	
Primary reflector diameter	36.6 m	36.6 m	
Surface tolerance (at rigging angle)	~600 µm	100 µm	
Max antenna rates	2 deg/sec (azimuth) 1.5 deg/sec (elevation)	5 deg/sec (azimuth) 2 deg/sec (elevation	
Wavelength	3 cm (X-band)	3 cm (X-band)	3 mm (W-band)
Bandwidth	1 GHz	1 GHz	8 GHz
Satellite imagery and range profiles	Near Earth and deep space	Near Earth and deep space	Near Earth

Photograph by Colin Lonsdale

The Haystack radome cap separation took place in May 2010. A band of radome panels was removed from the space frame to minimize deflections in strong winds. The radome was analyzed and prepared to withstand hurricane-force winds at all phases of construction.

Replacement of Haystack radome cap in September 2010. The cap was guided into position to mate with the lower portion of the radome by specially designed fittings. It is believed to be the largest space-frame radome to be separated and successfully reassembled.

In 2010, the major subassemblies of the new HUSIR antenna, including the aluminum back-structure, the quadrapod, and the steel transition structure were integrated and staged at the Haystack site. Installation of the antenna was executed during summer 2010 in a sequence of critical operations:

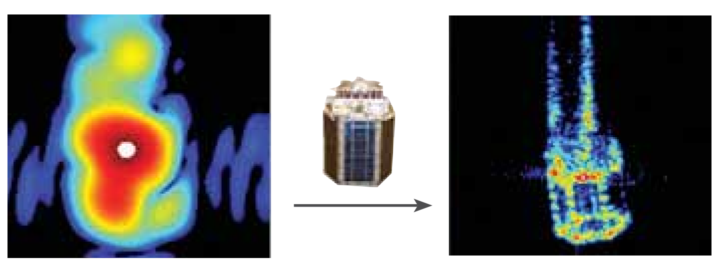
- Removal of the radome cap (115,000 lbs, 141 ft diameter)
- Removal of the old antenna back-structure (86,000 lbs) and counterweights
- Modifications of the existing yoke to receive the new antenna
- Removal of the temporary building housing the new antenna back-structure
- Installation of the new antenna transition structure (155,000 lbs)
- Installation of the new antenna back-structure (70,000 lbs)
- Re-installation of the radome cap

Each lift was backed up with rigorous engineering analysis and detailed procedures and drawings. The tight tolerances and large surface areas of the assemblies required planning the lifts for weather windows with near-calm wind speeds. The radome skin was also replaced during the summer.

With the radome enclosed, the 104 surface panel assemblies will be installed on the reflector and aligned to the 100 μm accuracy. The complete HUSIR system will be integrated and tested following the checkout of the new antenna control system.

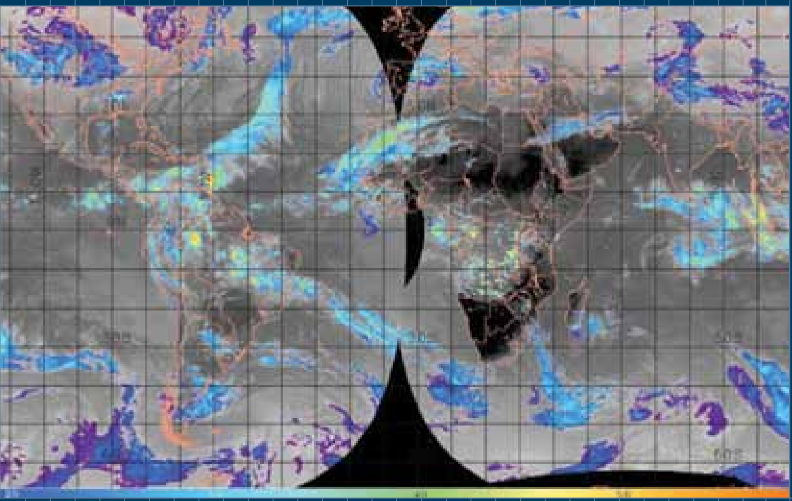
Photograph by Colin Lonsdale

Installation of the new primary reflector back-structure in September 2010. The minimum clearance between the transition structure and the back-structure while it was lowered was only 3 inches, so precise load control was critical. Thanks to precise engineering and metrology, all 64 bolt holes in the back-structure were perfectly aligned with their counterparts in the transition structure.

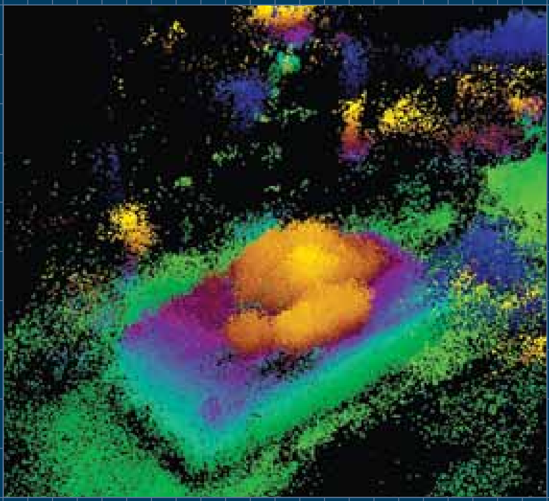


Haystack X-Band: 9.5–10 GHz **W-Band: 92–100 GHz**

Haystack upgrade to W-band (92–100 GHz) will enable inverse synthetic aperture radar (ISAR) imaging of satellites in low Earth orbits with much higher resolution than possible with the current X-band radar. ISAR images of a satellite model using compact range data.



MISSION AREAS AND TECHNICAL PROGRAMS



SPACE CONTROL

The Space Control mission develops technology that enables the nation's space surveillance system to meet the challenges of space situational awareness. Lincoln Laboratory works with systems to detect, track, and identify man-made satellites; performs satellite mission and payload assessment; and investigates technology to improve monitoring of the space environment, including space weather and atmospheric and ionospheric effects. The technology emphasis is the application of new components and algorithms to enable sensors with greatly enhanced capabilities and to support the development of net-centric processing systems for the nation's Space Surveillance Network.


Photograph courtesy of NASA

NASA Solar Dynamics Observatory launched from Cape Canaveral Air Force Station on 11 February 2010. The Extreme Ultraviolet Variability Experiment sensor carried on board is equipped with an advanced charge-coupled device focal plane developed by Lincoln Laboratory to measure solar emissions in the ultraviolet range.

Principal 2010 Accomplishments

- Studies and experiments with sensor hardware, processing software, and operational techniques were conducted to evaluate the benefits of new technology to U.S. Government sponsors. This work forms the basis of designing a comprehensive space situational awareness architecture for the nation.

- Lincoln Laboratory supported the development of the Space Fence by conducting performance and design trade studies, modeling designs, performing prototype risk reduction, and evaluating performance of candidate designs.

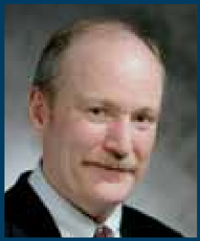
- The Millstone Hill Radar supported dozens of domestic and international space launches. The Haystack Long-Range Imaging Radar and the Haystack Auxiliary Radar provided additional characterization information on these launches. All three radars at the Lincoln Space Surveillance Complex (LSSC) were used by Laboratory analysts to provide timely damage assessment on rare satellite breakup events.

- The Extended Space Sensors Architecture (ESSA) Advanced Concept Technology Demonstration concluded with a successful demonstration netting space and missile defense sensors in real time. On the basis of a formal military utility assessment, ESSA was transitioned into a follow-on program to extend the net-centric architecture.

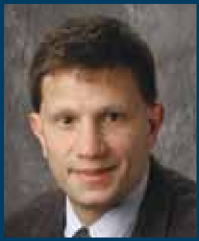
- The Laboratory developed novel neural network temperature and moisture retrieval algorithms as well as microwave modeling and calibration in support of the National Oceanic and Atmospheric Administration's forthcoming National Polar-orbiting Operational Environmental Satellite System and NASA's Aqua satellite, a component of NASA's Earth Observing System that has been collecting vast amounts of data on the Earth's weather and climate systems for almost ten years.

- Under Air Force sponsorship, Lincoln Laboratory is developing the Haystack Ultrawideband Satellite Imaging Radar (HUSIR). Completed components of the new 37 m antenna are being integrated at the LSSC. Over the next year, the new antenna will be integrated with the W-band and X-band transmitters and signal processing systems to allow inverse synthetic aperture radar imaging of satellites in low Earth orbits with much higher resolution than currently possible. Following integration and test, HUSIR will operate as a contributing sensor to the Space Surveillance Network. HUSIR will

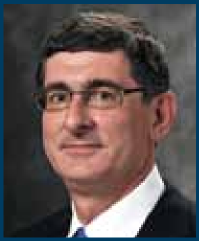
Leadership



Dr. Grant H. Stokes



Mr. Lawrence M. Candell



Mr. Craig E. Perini

The Firepond telescope on Millstone Hill has been recommissioned this past year as a space surveillance sensor.

Under the HUSIR program, the Haystack radar antenna surface is being upgraded to allow operation at W-band frequencies (92–100 GHz). Shown here is the antenna radome being prepared for the cap to be removed so that the new antenna surface can be installed. The radome surface—now over 20 years old—will be replaced as well.

also function as a test bed for research and development in support of space control and other national security applications.

- Development of the Space Surveillance Telescope continued with several notable milestones: fabrication of the primary mirror and corrector optics was completed, and fabrication of the secondary mirror is nearing completion; factory testing of the telescope mount gimbal was accomplished as was in-cell optical testing on the tertiary mirror. The telescope enclosure at the Atom Site on White Sands Missile Range, New Mexico, was completed, and the telescope mount gimbal was installed at site in 2010.

Future Outlook

- Activity will move from large-scale sensor development toward information extraction, integration, and decision support. The challenge will be to incorporate the widest possible set of data and automate the process of generating customized actionable products for a wide range of users.
- The Joint Space Operations Center (JSpOC) Mission System (JMS), the program of record, will equip JSpOC with tools for information integration and command and control. The net-centric nature of the JMS should allow integration of data from a broad variety of sensors. This net-centricity will be critical for evolving to a machine-to-machine–driven space situational awareness capability that can respond on timelines required to support survivability efforts.
- Sensor systems under development will bring new capability to the Space Control mission area. These systems include the Space-Based Space Surveillance–block 10, the Space Surveillance Telescope, HUSIR, and the Space Fence. Considerable time and effort will be required to fully assess the information available from the new sensors and make it most useful to operators.
- Emerging technical areas include advanced radar development, radar surveillance, space-object identification, electro-optical deep-space surveillance, collaborative sensing and identification, fusion, and processing.

AIR AND MISSILE DEFENSE TECHNOLOGY

In the Air and Missile Defense Technology mission, Lincoln Laboratory works with government, industry, and other laboratories to develop integrated systems for defense against ballistic missiles, cruise missiles, and air vehicles in tactical, strategic, and homeland defense applications. Activities include the investigation of system architectures, development of advanced sensor and decision support technologies, development of flight-test hardware, extensive field measurements and data analysis, and the verification and assessment of deployed system capabilities. The program includes a focused evaluation of the survivability of U.S. air vehicles against air defense systems. A strong emphasis is placed on the rapid prototyping of sensor and system concepts and algorithms, and the transfer of the resulting technologies to government contractors responsible for the development of operational systems.

Support to the Aegis BMD program includes performance analysis, discrimination algorithm development, and flight-test participation.

Principal 2010 Accomplishments

- Technology transfer of the next generation of the Radar Open System Architecture (ROSA II) approach continued with the acceptance testing of the C-band range system at Patrick Air Force Base, Florida, and with the initial integration phase of the C-band range system at Vandenberg Air Force Base, California.

- Development continued on the XTR-1 mobile instrumentation radar to provide key data during ballistic missile defense (BMD) tests that are beyond the reach of ground-based instrumentation. Testing was accomplished at the Laboratory's Firepond ground test site in Westford, Massachusetts, to validate key requirements. With the Laboratory's assistance, the radar is being integrated onto a ship for operations in 2011.

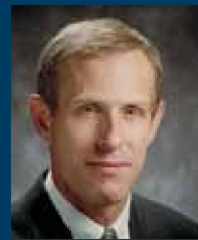
- Over-the-horizon radar (OTHR) has a potentially significant role in providing surveillance in support of homeland security and missile defense. Lincoln Laboratory has successfully prototyped and demonstrated new multiple-input/multiple-output signal processing techniques to reduce radar clutter and improve surveillance detection performance. Techniques were successfully demonstrated during the past year at the Relocatable OTHR facility in Virginia as well as on other OTH radars.

- At the direction of the Navy Program Executive Office for Integrated Warfare Systems, the Laboratory is designing, implementing, and testing a new electronic, ship decoy system for future Fleet defense against advanced antiship missiles. Prototype subsystems were designed and tested, culminating in a very successful Preliminary Design Review.

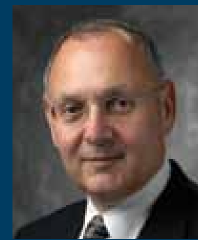
- During the past several years, Lincoln Laboratory has been developing a high-fidelity radar cross-section signature-modeling methodology and toolset known as the Augmented Point Scattering Model. This toolset is now being integrated into community-standard Threat Data Packages that will be used in planning BMD tests and for stimulating hardware-in-the-loop and digital simulations for system performance assessment.

Leadership

Dr. Hsiao-hua K. Burke



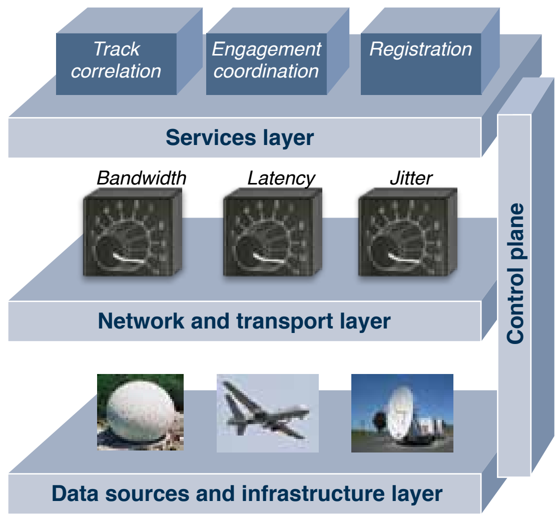
Dr. Andrew D. Gerber



Mr. Gerald C. Augeri

Mr. Dennis J. Keane

Test Bed Architecture for Missile Defense Applications



Lincoln Laboratory is implementing a net-centric architecture so that operations at the Reagan Test Site (RTS) can be conducted from remote locations. This architecture is also being adapted for use as a test bed for the development of MDA's Phased Adaptive Approach. (Above left) Modernized mission command-and-control center is now certified for use as the RTS mission control system; (above right) the test bed architecture, designed for assessing command and control, links sensors and shooters, services, communication networks, and battle managers.

Future Outlook

- In support of the Missile Defense Agency's (MDA) Phased Adaptive Approach, Lincoln Laboratory has initiated tasks in the areas of airborne infrared sensor technology development, technology trades for the Precision Tracking Space Sensor, test bed development for enhanced command, control, battle management, and communications (C2BMC), modeling and simulation, test planning, and operational architecture studies.

- In response to the existing and growing regional missile threat, Lincoln Laboratory continues to be a key member of the integrated test process that validates both the Ballistic Missile Defense System and its components. Efforts in improving the fidelity of sensor models in the digital testing, the robustness in ground testing, and decision support architectures in flight testing are all critical contributions to ensuring and enhancing the effectiveness of the Ballistic Missile Defense System.

- The Laboratory will continue to execute existing programs and develop new programs in the area of electronic warfare, with particular focus on Navy applications. These programs include the development of advanced electronic countermeasures for defense against antiship missiles, advanced electronic protection capabilities for airborne radar systems, and new concepts for the coordination of hard-kill and electronic warfare responses to missile threats.

- Sensor and weapon resource management and net-centric service-oriented architectures are not only becoming important technologies within the air and missile defense domains, but are also becoming key to allowing components within these domains to contribute across other domains. By leveraging existing efforts such as ROSA, which addresses radar infrastructure in a distributed and open architecture model, and the Range Distributed Operations, which address radar coordination and control, the Laboratory has developed a model of a plug-and-play test bed that has been demonstrated in live-fire mission tests involving missile defense, space situational awareness, and cyber components, and that will be used as the Enhanced C2BMC prototype for MDA's Phased Adaptive Approach.

COMMUNICATION SYSTEMS

The Communication Systems mission works to enhance and protect the capabilities of the nation's global defense networks. Emphasis is placed on synthesizing system architectures, developing component technologies, building and demonstrating end-to-end system prototypes, and then transferring this technology to industry for deployment in operational systems. Current efforts span all network layers (from physical to application), with primary focuses on radio-frequency (RF) military satellite communications (MILSATCOM), net-centric operations, free-space laser communications, line-of-sight networking, speech and language processing, and computer network operations.

The Laboratory developed and distributed high-fidelity behavioral models of the mobile ad hoc networking waveforms that will be used in next-generation tactical radios. The models can be used to evaluate and visualize large-scale mobile ad hoc networks in real time.

Principal 2010 Accomplishments

- Lincoln Laboratory demonstrated cross-domain information sharing among ballistic missile defense, space situational awareness, and cyber security sensor and processing resources during a live-fire exercise.

- The Laboratory completed lab and field testing of a high-data-rate waveform for airborne intelligence, surveillance, and reconnaissance (ISR) readout over the Wideband Global SATCOM system. This waveform will be transferred to the Global Hawk and other airborne ISR platforms.

- A resource-brokering architecture was developed, and an initial implementation that dynamically composes and tasks work flows of sensing, communication, processing, archival, and analyst resources was successfully demonstrated.

- The Laboratory's best-in-class language identification technology was integrated into DoD systems.

- Lincoln Laboratory achieved best speech translation performance for Arabic and Turkish translation in an international evaluation and developed a real-time distributed system for speech translation.

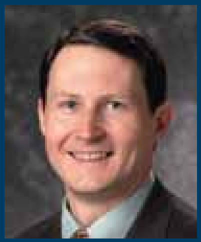
- The Laboratory's social network analysis and intent recognition algorithms were evaluated on a large international terrorist database. The algorithms demonstrated promising initial results in identifying social networks and the roles of various actors in the network, as well as in predicting the outcome of significant events such as hostage situations.

- Lincoln Laboratory successfully demonstrated error-free data transfer over an air-to-ground laser communications (lasercom) link, operating at 2.67 Gb/sec over 60 km ranges, from an aircraft at 12 kft to a ground terminal. The airborne lasercom system, which operates at eye-safe power levels from a small (~2.5 cm) aperture, employs spatial and temporal diversity techniques to mitigate signal fading caused by atmospheric turbulence.

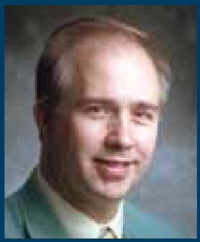
- The Laboratory conducted research in advanced network coding techniques to improve the aggregated capability provided by interconnecting multiple heterogeneous link types and networks.

- Installation and checkout of the Advanced Extremely High Frequency (AEHF) interim command-and-control terminals were completed. The Laboratory supported the preparations for the launch and calibration of the first AEHF satellite.

Leadership

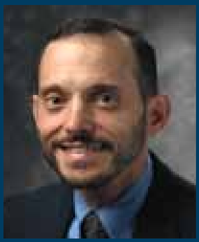


Dr. J. Scott Stadler



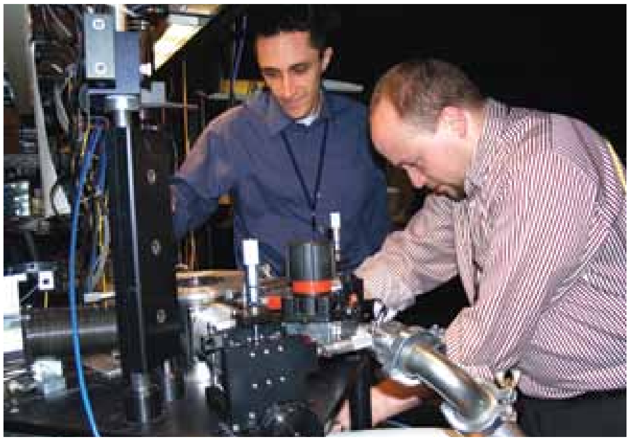
Dr. Roy S. Bondurant

Mr. Stephan B. Rejto



Dr. Marc A. Zissman

The Laboratory created a prototype of an advanced MILSATCOM-on-the-move vehicle. This vehicle can connect to multiple satellite systems, including those that are resistant to jamming or other disruptions, such as the Advanced Extremely High Frequency system.



Laboratory researchers, including Eric Dauler (left) and Jamie Kerman (right), demonstrated the potential for secure quantum key distribution at rates of 1.85 Mbit/sec over more than 100 km of fiber, exceeding previous results by two orders of magnitude. The demonstration used the Laboratory's high-efficiency, high-speed, low dark count rate superconducting nanowire single-photon detectors, and leveraged its expertise in developing high-sensitivity classical differential-phase-shift-keying optical communication systems.

- Lincoln Laboratory developed a detailed technical specification and a government reference implementation of the Multifunction Advanced Data Link communication system, the next-generation low-observable link for fighter and bomber aircraft.
- A brassboard implementation of an optical space flight modem operating near theoretical sensitivity limits over data rates ranging from 10 Mbps to 2.5 Gbps was demonstrated.
- Hardware test-set implementation and field testing were performed to quantify the impact of pollution and other scattering constituents in diverse urban and rural environments.
- The Laboratory held a successful Critical Design Review for the NASA Lunar Laser Communications Demonstration system, currently being designed and built for a planned launch in March 2013.

Future Outlook

- Lincoln Laboratory will continue to perform large-scale demonstrations of enabling technologies for Net-Centric Operations. These demonstrations will combine Laboratory-developed services with DoD Net-Centric Enterprise Services to integrate ballistic missile defense, space situational awareness, and cyber systems.
- The Laboratory will extend its work on information extraction from speech and text, including extraction of entities, links, and events, and will apply that work to enhanced social network analysis and intent recognition.
- Development of architectures and technologies to provide new capabilities for the space, ground, and airborne layers of DoD's communications infrastructure will continue.
- The resource-broker architecture will be evolving to include more advanced planning algorithms.
- Laser communication technology efforts will focus on investigating clouds as a transmissive or reflective channel and as the space/air-to-submarine channel.

INTELLIGENCE, SURVEILLANCE, & RECONNAISSANCE SYSTEMS AND TECHNOLOGY

The Intelligence, Surveillance, and Reconnaissance (ISR) Systems and Technology mission conducts research and development into advanced sensing concepts, signal and image processing, high-performance computing, networked sensor architectures, and decision sciences. This work is focused on providing improved surface and undersea surveillance capabilities for problems of national interest. The Laboratory's ISR program encompasses airborne imaging and moving target detection radar, radio-frequency (RF) geolocation systems, electro-optic imaging, laser radar, and acoustic sensing. For such systems, the Laboratory typically performs phenomenology analysis, system design, component technology development, and significant experimentation. Successful concepts often develop into experimental prototype ISR systems, sometimes on surrogate platforms, that demonstrate new capabilities in operationally relevant environments.

The Multi-Aperture Sparse Imager Video System (MASIVS) is a custom-designed, four-focal-plane system that achieves 880 Mpixels at 2 frames/sec in color. Mounted on the Cessna aircraft, MASIVS was demonstrated in a collection of wide-area persistent imaging over the White Mountains in New Hampshire.

Principal 2010 Accomplishments

- High-performance RF receivers based on RF integrated circuits were shown to provide unprecedented performance while consuming very little size, weight, and power—all crucial considerations for RF sensor systems applications on smaller unmanned aerial vehicles.

- The Laboratory has been developing novel airborne radar techniques to detect and track ground moving targets. New radar modes using feature-based digital signal processing algorithms that exploit unique target phenomenology have been tested and shown to provide reliable target classification.

- In support of national needs for wide-area persistent surveillance, the Laboratory has continued to develop and demonstrate end-to-end systems for collection and exploitation of these revolutionary data sets. In 2010, the Laboratory flew gigapixel-class visible and infrared airborne systems coupled with onboard data processing and a ground processing toolset. The processing and exploitation systems were deployed to a forward operating location.

- Development began on the prototyping of next-generation techniques for exploitation of ground moving target indicator sensor data. This work includes developing advanced moving target tracking algorithms, modeling behavior patterns, and developing automated algorithms to detect anomalous activity. This research is supported with data collected by Laboratory airborne ISR test bed assets.

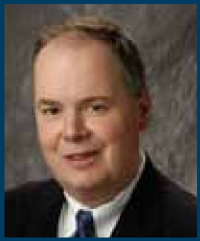
- Using an open system architecture and ruggedized commercial off-the-shelf (COTS) hardware, Lincoln Laboratory developed a real-time parallel synthetic aperture radar image processing system for rapid integration on an airborne platform.

- For the Real-time Enhanced Situation Awareness program, the Laboratory developed and initiated deployment of a real-time fused situational awareness application. The open architecture specifications, standards, and technologies are serving as the Air Force prototype for future net-centric systems.

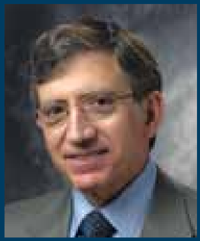
- The Laboratory successfully demonstrated 1.3 Gbits/sec wireless communication over a 75-meter link from a vehicle traveling up to 35 miles per hour. Advances in

Leadership

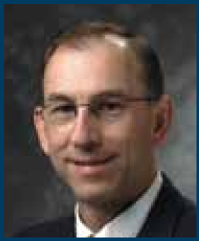
Dr. Robert T-I. Shin



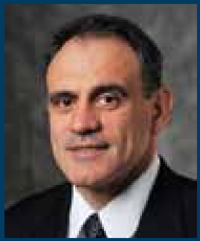
Dr. Robert G. Atkins



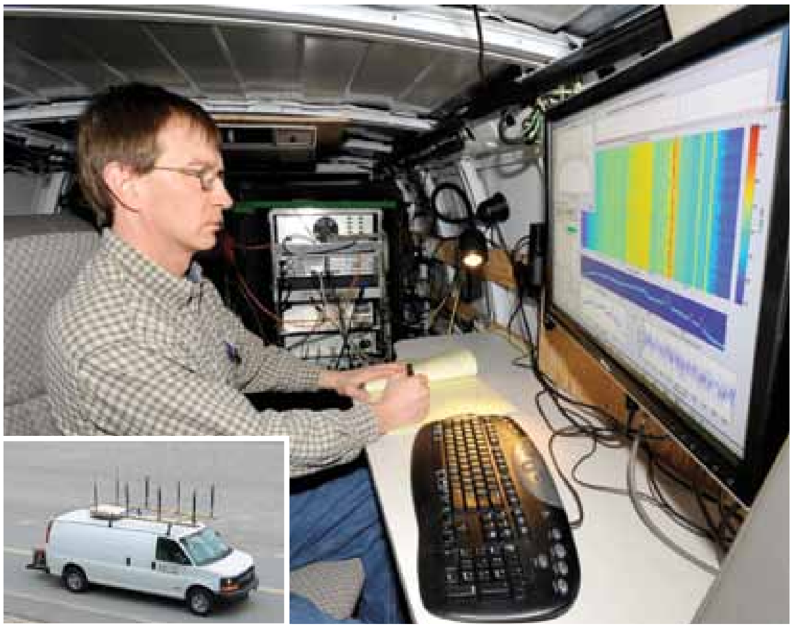
Dr. Curtis W. Davis III



Dr. James Ward



Dr. William D. Ross



(Above) The Laboratory developed and flight-tested a new airborne radar on a Twin Otter aircraft prior to the system's being integrated on a government-furnished aircraft for operational testing. The photograph is of the team and the Twin Otter.

(Left) The Laboratory operates a mobile signal analysis capability for developing and testing new RF sensing and communication capabilities. The van (inset) is equipped with a roof-mounted broadband antenna array and significant data recording and computing hardware for collection and field data analysis.

multiple-input/multiple-output communications, robust waveform design, and signal processing techniques enable extremely high-data-rate links in challenging urban environments.

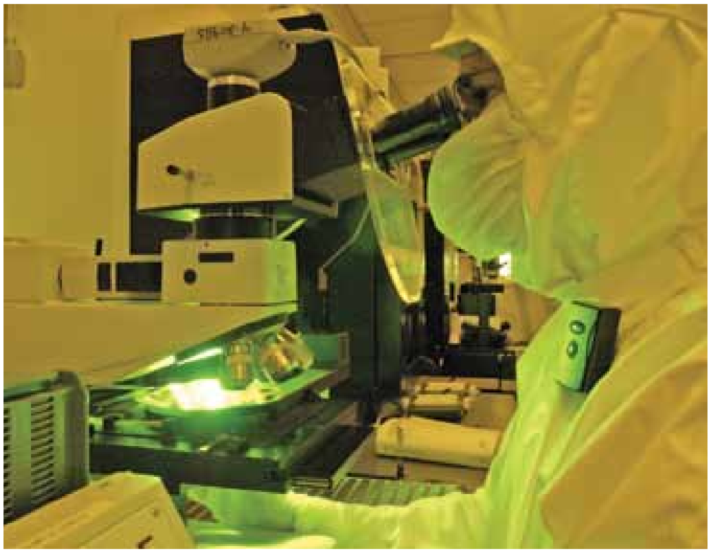
- A new research activity in the theory and application of graph detection algorithms was initiated, in part to develop more effective methods for discovering insurgent networks through analysis of persistent surveillance sensor data. The high computational demands of these algorithms are motivating research into new parallel computing architectures designed for the sparse matrix computations inherent to this class of algorithms.

Future Outlook

- The ISR Systems and Technology mission is expected to receive increasing national investment to develop and field improved systems for irregular and conventional warfare, and to provide much better integration of ISR capabilities between the armed services and intelligence agencies.
- Improved sensing modes that effectively detect, classify, and geolocate individual vehicles and personnel over wide areas are needed. Research into methods for detecting the manufacture or transport of explosives and weapons of mass destruction is expected to continue. Development of exploitation techniques that fuse multiple-sensor data to detect indicators of threat behavior will be an active research area.
- Technologies for accessing, sharing, and visualizing large data volumes are needed, as are methods for exploiting such data with the timeliness to provide agile responses. Increasing activity in decision support technologies, distributed high-performance computing, and web-based service-oriented architectures for ISR systems is envisioned to address these needs.

ADVANCED TECHNOLOGY

Research and development in Advanced Technology focus on the invention of new devices, the practical realization of those devices, and their integration into subsystems. Although many of these devices continue to be based on solid-state electronic or electro-optical technologies, recent work is highly multidisciplinary, and current devices increasingly exploit biotechnology and innovative chemistry. The broad scope of Advanced Technology work includes the development of unique high-performance detectors and focal planes, 3D integrated circuits, biological- and chemical-agent sensors, diode lasers and photonic devices using compound semiconductors and silicon-based technologies, microelectromechanical devices, RF components, and unique lasers including high-power fiber and cryogenic lasers.



A process engineer inspects a large-format charge-coupled-device (CCD) wafer being fabricated in the class-10 clean room of Lincoln Laboratory's Microelectronics Laboratory, which fabricates some of the world's best CCD imagers for use in ground-based and space-based applications.

Principal 2010 Accomplishments

- Significant additional improvements in cryogenic Yb:YAG lasers were achieved: higher continuous wave power, demonstration of ultra-short-pulse operation, and lasers with the needed beam quality, form factor, and reliability to be usable in near-term DoD application test beds.

- Two improved versions of photon-counting detectors were demonstrated. One array, for laser radar, had greatly decreased optical cross talk and showed unprecedented single-photon detection efficiency. The second array had an asynchronous readout mode for laser communications. Earlier detector technology was transferred and is now available from commercial suppliers.

- A new high-frame-rate charge-coupled-device (CCD) imager was demonstrated for adaptive optics. This CCD uses an output circuit that has only one-half the noise of previous adaptive-optics CCDs.

- The development of superwideband compressive receivers continued, with a successful flight demonstration of geolocation capability over multi-GHz bandwidth.

- The Laboratory remains the only organization providing access for the DoD research community to high-density 3D integrated circuit technology. The third multiproject run was recently completed.

- In a follow-up to a successful field demonstration of standoff detection of trace chemical explosives via photodissociated laser-induced fluorescence, a seed laser was developed with spectral and temporal profiles optimized for excitation of such trace chemicals.

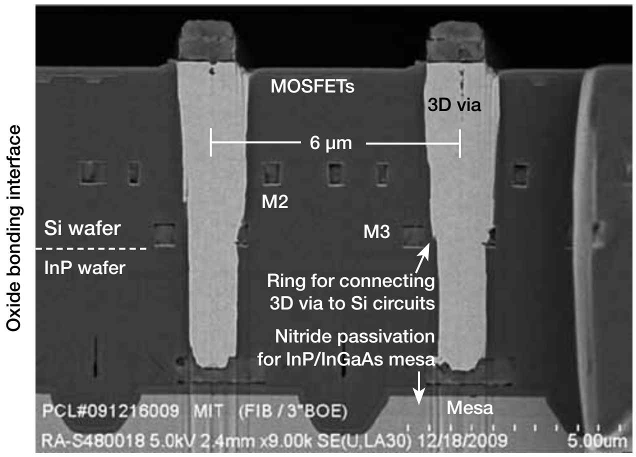
- A decades-long goal in the laser community has been to combine the output beams of many diode lasers in order to produce an electrically efficient high-power laser source. The Laboratory demonstrated over 45 W coherent output from an array of six 20-diode modules that exploit the near-ideal beam quality of the slab-coupled optical waveguide structure invented at Lincoln Laboratory.

- The Laboratory's pioneering work on graphene-on-insulator (GOI) electronics was presented in a paper recently recognized by the IEEE Electron Device Society George E. Smith Award as the best paper published in *IEEE Electron Device Letters* in the past year. In this work, the Laboratory reported on some of the first transistors measured on GOI material. The GOI material development was carried out jointly with researchers on MIT campus; transistor fabrication was done in the Laboratory's Microelectronics Laboratory.

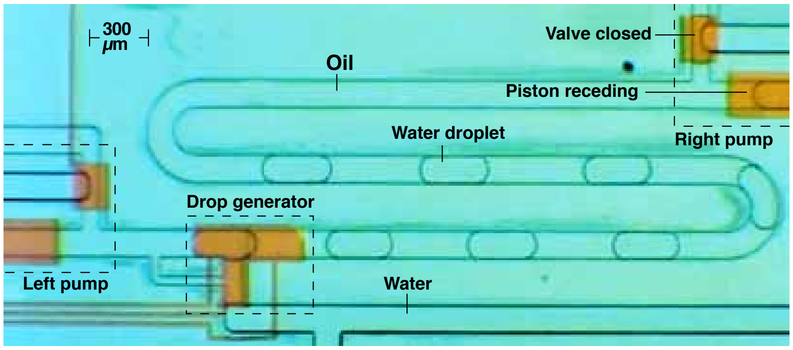
- Progress was made on the effort to extend the lifetimes of superconducting flux quantum bits (qubits). One factor limiting qubit lifetimes is classical dissipation losses in the materials

Leadership

Dr. David C. Shaver Dr. Craig L. Keast Dr. Charles A. Primmerman



The short-wave infrared detector with 6-micron pixel pitch is enabled by 3D integration of InGaAs photodiodes on InP substrate with silicon-on-insulator complementary metal-oxide semiconductor pixel readout circuitry. A paper describing this work received the Best Paper Award at the 2009 IEEE International 3D Systems Conference.



This top-down photograph of a microfluidic circuit using electrowetting technology shows how the water droplets move left to right when the right pump works in the "pull" mode. Candidate applications for microfluidic circuits include an array of DoD biotechnology needs.

used to construct the qubit. The quality factor of half-wave resonators fabricated from candidate superconductors and substrates was measured at power levels appropriate for qubit operation (single photons). World-record results (quality factors of 400,000) were observed in Al and Re films on sapphire and silicon substrates at temperatures of 10 mK.

- Preliminary results demonstrate that novel antiviral therapeutics are effective against Tacaribe arenavirus and Dengue flavivirus in cultured cells. These results indicate that the Laboratory's therapeutics are effective against representative members from the arenavirus and flavivirus hemorrhagic fever virus families, whose more serious members include Lassa, Junin, West Nile, and Yellow Fever viruses. More extensive cell tests with these and other viruses are under way.

Future Outlook

- Innovative thrusts for emerging DoD needs result from multidisciplinary interactions enabled by the Laboratory's competencies in imaging focal planes, silicon circuit technology using 3D integration, compressive receivers, optical lithography, diode and solid-state lasers, photonic devices, and superconductive electronics.
- The scope of applications for Geiger-mode (GM) single-photon detection technology is expanding, with development of GM detectors that operate at short- and mid-wave infrared wavelengths and of "smarter" readout integrated circuits for higher-speed, lower-power photon counting.
- Significant activities will continue to support both nearer-term and longer-term DoD needs for high-energy lasers. Technologies will range from cryo-cooled or slab-coupled gain media to both spectral and coherent beam combining.
- Chemical and biological sensing technologies will be further advanced for biological and chemical detection of explosives, toxins, and bioagents. Mid-infrared quantum-cascade lasers promise new capabilities in infrared countermeasures and chemical sensing.
- The size and speed scaling of silicon devices has ended, and potential pathways "beyond silicon" will continue to be explored, including 3D mixed-material circuit integration, graphene electronics, and superconductive electronics.
- The Laboratory will complete a significant three-year recapitalization of its class-10 Microelectronics Laboratory. The upgraded facility will sustain full 200 mm diameter wafer processing with sub-90 nm device feature sizes.

TACTICAL SYSTEMS

In the Tactical Systems mission, Lincoln Laboratory focuses on assisting the Department of Defense to improve the acquisition and employment of various tactical air and counterterrorist systems. The Laboratory does this by helping the U.S. military understand the operational utility and limitations of advanced technologies. Activities focus on a combination of systems analysis to assess technology impact in operationally relevant scenarios, rapid development and instrumentation of prototype U.S. and threat systems, and detailed, realistic instrumented testing. The Tactical Systems area is characterized by a very tight coupling between the Laboratory's efforts and the DoD sponsors and warfighters involved in these efforts. This tight coupling ensures that the analysis that is done and the systems that are developed are relevant and beneficial to the warfighter.

The Laboratory has developed several quick-reaction counterterrorism capabilities that have been transitioned to operational demonstration and use.

Principal 2010 Accomplishments

- Lincoln Laboratory is conducting a comprehensive assessment of options for U.S. Air Force airborne electronic attack. A major focus has been the development of test infrastructure, including a new Airborne Countermeasures Test System and modern threat radar emulators.

- Lincoln Laboratory continued a detailed assessment of the impact of digital radio-frequency memory–based electronic attack on air-to-air weapon system performance. Results from flight testing, systems analysis, and hardware-in-the-loop laboratories have been used to improve U.S. electronic protection systems.

- Lincoln Laboratory is conducting an assessment of the capabilities of infrared sensors and seekers. A major focus has been the development of instrumentation to captive carry a long-wave infrared search-and-track (IRST) and imaging infrared (IIR) seeker.

- A number of assessments were performed to examine the impact of exporting advanced military systems. These assessments were used as part of the decision-making process for a number of major export programs.

- The Laboratory demonstrated an advanced airborne signals intelligence (SIGINT) capability in an operational demonstration outside the continental United States. The Laboratory is transitioning the technology to industry for use in a next generation of advanced SIGINT capabilities.

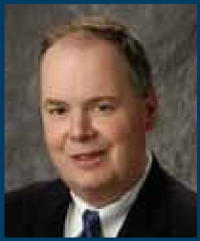
- A robot-mounted sensor technology was transitioned into production and successful operational use by Route Clearance Engineer teams.

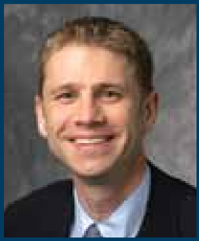
- Comprehensive support to the Joint Counter Radio-Controlled Improvised Explosive Device (IED) Electronic Warfare program continues. Laboratory-developed architectures and specific technologies are being transitioned for use in the next generation of counter-IED electronic attack systems.

- The Laboratory is continuing a significant effort to develop and transition two novel airborne sensor systems for use in a quick-reaction, multiple-intelligences (multi-INT), intelligence, surveillance, and reconnaissance (ISR) capability. Both systems will be fielded this year.

Leadership


Dr. Robert T-I. Shin


Dr. Robert G. Atkins


Dr. Justin J. Brooke


Dr. Kevin P. Cohen


The Laboratory is rapidly developing advanced sensors. Two such payloads were developed by the Laboratory for this quick-reaction ISR capability.


The Laboratory completed the development and integration of instrumentation and control systems to captive carry infrared systems on the Airborne Seeker Test Bed. Several initial data-collection flights were conducted to characterize sensor performance and the infrared background environment.

- The Laboratory developed a strategy and architecture for IED defeat, which allow a cost-effective scaling of defense capabilities.
- An effort was initiated to support the U.S. Air Force with assessments and risk reduction in the area of information dominance.
- The Laboratory is prototyping a new type of ground-penetrating radar technology and will develop a field-worthy prototype for operational demonstration.

Future Outlook

- Lincoln Laboratory will continue to provide assessments and testing in support of U.S. Air Force acquisition decisions in air vehicle survivability, electronic attack, and other areas. Test assets, such as the Airborne Countermeasures Test System, and development of modern threat radar emulators will evolve to support these efforts.
- The Laboratory will play a larger role supporting the U.S. Air Force in the area of information dominance. Initial activities will include assessment of future ground moving target indicator radar options and development of a roadmap for counterterrorism efforts.
- Rapid development capabilities will continue to expand to address continuing needs in many applications.
- The Laboratory's efforts in the counterterrorism area will increase, with greater emphasis on development and demonstration of ISR architectures. Specific trends include multi-INT integration and the development of more advanced sensors for small unmanned aerial vehicle platforms. The Laboratory continues to rapidly develop advanced sensors.

HOMELAND PROTECTION

The Homeland Protection mission is supporting the nation's security by innovating technology and architectures to help prevent terrorist attacks within the United States, reduce the vulnerability of the nation to terrorism, minimize the damage from terrorist attacks, and facilitate recovery from either man-made or natural disasters. The broad sponsorship for this mission area spans the Department of Defense, the Department of Homeland Security (DHS), and other federal, state, and local entities. Recent efforts include architecture studies for the defense of civilians and facilities against biological attacks, development of the Enhanced Regional Situation Awareness system for the National Capital Region, the assessment of technologies for border and maritime security, and the development of architectures and systems for physical infrastructure protection.

An emergency responder is able to access real-time critical information on a ruggedized laptop computer, a "toughbook," mounted in his vehicle. The toughbook is connected via the Lincoln Distributed Disaster Response System to the command-and-control center managing the wildfire exercise.

Principal 2010 Accomplishments

- The Laboratory partnered with the California Department of Forestry and Fire Protection to prototype a collaborative command-and-control system for disaster response. This prototype is a continuation of the vision, first demonstrated during 2009 in California's Riverside and San Diego counties, to apply this architecture to controlling wildfires (see page 9 for more on this technology).

- Technology assessments for securing the northern and southern borders of the United States included quantifying the detection, classification, and false-alarm characteristics of a network of unattended ground sensors that utilize seismic and acoustic sensing modalities.

- The field-deployable Accelerated Nuclear DNA Equipment program is an 18-month effort sponsored by the Departments of Defense, Justice, and Homeland Security to develop automated, rapid, human DNA profiling capabilities for field biometrics and forensics capabilities. The program includes industry participation (Network Biosystems) and has developed a six-channel prototype that can automatically produce DNA profiles within one hour. The Laboratory identified efficient sample collection tools and techniques and began experiments on the collection of touch DNA from forensic samples. The program has also developed a secure framework for processing, storing, and communicating DNA profiles.

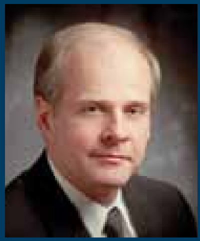
- The Imaging System for Immersive Surveillance (ISIS) consists of a custom 240 Mpixel sensor, a multi-terabyte data archive, a multiple-user video interface, and automated video exploitation algorithms for ground-based surveillance in support of critical infrastructure protection. The ISIS system, sponsored by the DHS Science and Technology Directorate, is being operationally tested in collaboration with the Massachusetts Port Authority.

- Lincoln Laboratory has a key role in the design of the command-and-control architecture for NORAD/NORTHCOM's "Gap Filler" initiative to provide wide-area surveillance for North America. Specific technologies being developed are sensor and data fusion, threat assessment and alerting, and a network architecture that supports joint, interagency, intergovernmental, and multinational partners in air security.

- The Laboratory has continued to support the DHS in evaluating technologies for homeland air security. Key contributions included architectural development, detailed sensor and

Leadership

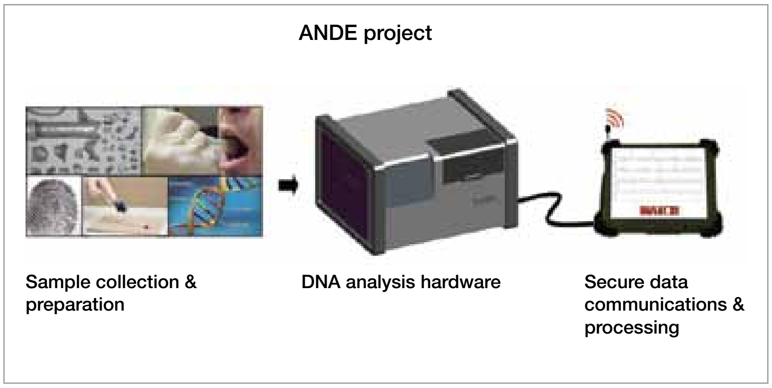
Dr. Israel Soibelman



Mr. James M. Flavin

Dr. Timothy J. Dasey

The Imaging System for Immersive Surveillance provides wide-area video surveillance in support of critical infrastructure protection. A 240-million-pixel sensor provides 360° coverage, and software provides multiple users with virtual pan-tilt-zoom interfaces and automated activity detection capabilities.



(Above) The Accelerated Nuclear DNA Equipment (ANDE) project enables the automated processing of 15 human DNA samples in less than an hour. ANDE can be deployed to expeditionary laboratory facilities to enhance the timely processing of reference DNA samples. ANDE consists of DNA collection tools and methods, DNA processing hardware, and secure data communications to remote DNA databases.

siting analysis, and risk reduction through high-fidelity modeling of emergent surveillance technologies.

- A rapid biological sensing pilot system using commercial sensing technology and Lincoln Laboratory sensor fusion algorithms is being developed and will be evaluated in a subway system. If successful, this system will allow for evacuations and facility closures rapidly enough that bioagent exposures will be reduced.

- The Laboratory led the execution of a military utility assessment that evaluated the operational capabilities of sensing systems to counter emerging chemical threats. The data from this assessment were used to support the fielding of improved equipment sets to the warfighter.

Future Outlook

- Securing and defending U.S. borders motivates the need for an integrated air, land, and maritime architecture. This need will spur advancements in wide-area sensors, such as over-the-horizon radar, as well as in advanced data fusion and decision support tools. Lincoln Laboratory will continue to apply its core strengths in advanced sensors, signal processing, service-oriented architecture, and rapid prototyping to enable an integrated architecture.

- Analysis, development, and testing of advanced chemical and biological defense solutions will continue, with strong contributions expected in countering emerging threats.

- The development of next-generation forensics technologies will likely expand to field-portable DNA analysis that includes rapid latent DNA analysis and to enhancements in other forensic measurement modalities.

- The Laboratory will develop and assess technologies and architectures to address critical infrastructure protection. Through partnerships with local, state, and federal operational communities at airports, mass transit sites, ports, and event venues, the Laboratory will leverage strengths in architecture development, sensors, and situational awareness systems to enhance capabilities.

- Lincoln Laboratory will demonstrate a distributed disaster response capability to serve as a model for the State of California and will establish a National Response Test Bed to support multiagency responses to extreme-scale disasters.

AIR TRAFFIC CONTROL

Since 1971, Lincoln Laboratory has supported the Federal Aviation Administration (FAA) in the development of new technology for air traffic control. This work initially focused on aircraft surveillance and weather sensing, collision avoidance, and air-ground data link communication. Today, the program has evolved to include a rich set of safety applications, decision support services, and air traffic management automation tools. A focus of the current program is support for the FAA's Next Generation Air Transportation System (NextGen). Key activities include the operation of a national-scale integrated weather-sensing and decision support prototype, testing and technology transfer of a runway incursion prevention system, development of a future air traffic control tower automation platform, and the development of a net-centric, system-wide information management system.

Photographs by Richard Ferris

Ramp Control Tower at Newark Liberty International Airport. Lincoln Laboratory's Corridor Integrated Weather System and Route Availability Planning Tool display is at upper left.

Principal 2010 Accomplishments

- The Laboratory-developed Corridor Integrated Weather System (CIWS) was reengineered to provide continental United States (CONUS) coverage and a robust configuration suitable for handoff to the FAA for long-term operation.

- A prototype NextGen weather system providing 8 hr CONUS-wide storm forecasts was developed by blending CIWS technology with a high-resolution, rapid-update numerical weather prediction model and is being evaluated in operational air traffic control (ATC) facilities in 2010.

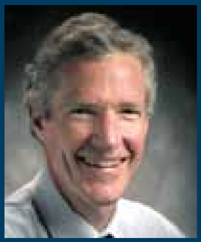
- Lincoln Laboratory continues to support the FAA's acquisition of a national Automatic Dependent Surveillance–Broadcast (ADS-B) system. ADS-B is a system in which each aircraft broadcasts its aircraft-determined position, intent, and status information on the order of once each second. This broadcast position information can be received by other aircraft and by ground stations, providing robust air-to-ground and air-to-air surveillance. The Laboratory analyzed radar and ADS-B fusion algorithms and surveillance requirements needed for ATC at key ADS-B sites. This work included the analysis of wide-area multilateration (locating aircraft by computing time difference of arrival of multiple radio signals) as a backup for ADS-B.

- The Laboratory is working with the FAA to refine concepts for a next-generation Multi-function Phased Array Radar (MPAR) that would provide surveillance services currently acquired from separate ATC and weather radar networks. Current activity is focused on development and testing of active array panels that meet performance and cost requirements established for MPAR in previous Laboratory studies.

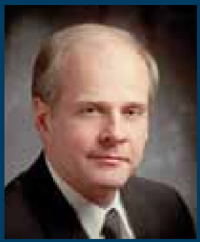
- A Tower Flight Data Manager for future air traffic control towers is under development. The system includes integrated surveillance and electronic flight-data displays as well as decision support tools to aid controllers in managing airport configuration, runway assignment, aircraft sequencing, taxi routing, and departure route assurance. A prototype was developed and tested in simulation; field evaluations are planned at the Dallas/Fort Worth International Airport for late 2010 to 2011.

- The Runway Status Lights system continues successful operational evaluation at Dallas/Fort Worth International Airport and the Los Angeles International Airport. These airports exposed the effectiveness of Takeoff Hold Lights and Runway Entrance Lights. An operational evaluation is now under way at Boston Logan International Airport to assess the effectiveness of status lights at intersecting runways.

Leadership

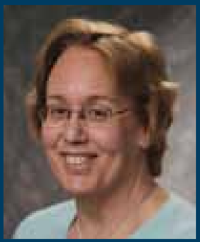


Dr. Mark E. Weber



Mr. James M. Flavin

Dr. James K. Kuchar



Dr. Marilyn M. Wolfson

Departure at New York LaGuardia Airport. To help the FAA alleviate weather-related delays, Lincoln Laboratory is developing systems that will be incorporated into the Traffic Flow Management System.

- Lincoln Laboratory completed detailed National Airspace traffic-density models as well as detailed trajectory models of noncooperative aircraft, including ultralights, gliders, and balloons. The Laboratory also initiated the development of a test bed for evaluating sense-and-avoid systems as a means of safely integrating unmanned aircraft systems into civilian airspace.

- Laboratory researchers have been assessing the performance of the Traffic Alert and Collision Avoidance System (TCAS) in airspace with reduced vertical separation, as well as supporting the FAA in the definition of a next-generation TCAS that will leverage information from ADS-B.

Future Outlook

- The Laboratory will continue developing NextGen ATC tower surveillance, automation, and decision support capabilities to improve safety and efficiency at conventional, on-airport towers and to potentially permit migration of ATC services to remote locations at appropriate airports.

- Lincoln Laboratory will assume an increasingly influential role in the definition and development of the FAA's future System Wide Information Management architecture that encompasses surveillance, weather, and flight-data exchange.

- Laboratory-developed thunderstorm forecasting capabilities and associated decision support tools will play an increasingly important role in alleviating weather-related delays. The Route Availability Planning Tool (RAPT), a system that expedites departures during convective weather, will be deployed to airports and be incorporated into the FAA's Traffic Flow Management System.

- Applications are planned to leverage ADS-B to improve safety, efficiency, and capacity in congested airspace. Lincoln Laboratory will be instrumental in developing safety cases for these applications and in demonstrating robustness during "off-nominal" conditions.

- Emphasis is on development and testing of next-generation aircraft-separation assurance on the airport surface and during flight. This effort includes evolution of collision-avoidance systems such as TCAS and Runway Status Lights, as well as simulation, analysis, and testing of future concepts.

ENGINEERING

Fundamental to the success of Lincoln Laboratory is the ability to build hardware systems incorporating advanced technology. These systems are used as platforms for testing new concepts, as prototypes for demonstrating new capabilities, and as operational systems for addressing warfighter needs. To construct the variety of systems used in programs across all mission areas, the Laboratory relies on its extensive capabilities in mechanical design and analysis, optical system design and analysis, aerodynamic analysis, mechanical fabrication, electronics design and assembly, control system development, system integration, and environmental testing. These capabilities are centered in the Laboratory's Engineering Division, which is an important contributor to many of the Laboratory's most successful efforts.

The 140,000 lb transition structure is rotated in preparation for integration of the Haystack Ultrawideband Satellite Imaging Radar.

Principal 2010 Accomplishments

- Lincoln Laboratory fabricated and shipped four Missile Alternative Range Target Instrument (MARTI) payloads to San Nicolas Island, California, for launch. MARTI provides in situ radiometric diagnostics for Airborne Laser testing. In preparation for delivery to the field, the payloads were taken to Wallops Island Flight Facility in Virginia for integration and test with the booster. Two payloads were launched, and the MARTI data was successfully collected on missions that were important milestones for the Airborne Laser program.

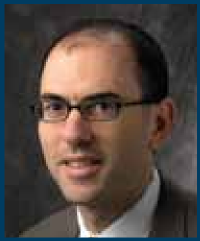
- Fabrication of all major antenna components for the Haystack Ultrawideband Satellite Imaging Radar (HUSIR) were completed. When integrated, the components—a 120 ft diameter aluminum back-structure, a 140,000 lb steel transition structure, 104 precision subframe/surface panel assemblies, and a 10 ft diameter subreflector—form the Cassegrain antenna, which requires an extremely precise surface figure of 100 µm over its 120 ft diameter.

- The Laboratory continued work on developing spacecraft payloads for laser communications, including the Lunar Laser Communications Demonstration (LLCD) payload that will be launched into lunar orbit on a NASA satellite. The LLCD optical module is an innovative design that allows the system to maintain optical alignment and precision pointing for optical communication from space.

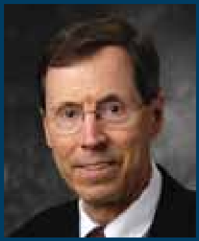
- In the robotics area, work was begun to bridge the gap between academic robotics and practical applications for DoD programs. An example application is autonomous mapping of GPS-denied interior spaces, which is necessary to localize data (e.g., video) acquired by exploration robots doing damage assessment or subterranean exploration. The Laboratory has demonstrated real-time, autonomous mapping with a single robot. A map is optimized and extended in real time as the robot autonomously explores a space.

- Rapid prototyping continues to expand at the Laboratory. The Rapid Prototyping Group focused on systems development, completing prototype systems for detecting improvised explosive devices (IEDs) and for gathering and processing high-data-rate imagery. Facility improvements were also made, including a new office space designed to facilitate enhanced collaboration for rapid execution.

Leadership



Dr. Eliahu H. Niewood



Dr. William R. Davis

Dr. Michael T. Languirand

(Above) An electronic discharge machine is used for precision component fabrication.

(Left) The launch team is shown with a Lincoln Laboratory Missile Alternative Range Target Instrument integrated on a rocket used for Airborne Laser test bed characterization.

Future Outlook

- The Laboratory created a new group focused on integrated and insightful engineering analysis and testing. This enhanced analysis capability will help drive early program planning and concept development, explore mission and design trade spaces, and drive critical design trades throughout the design cycle.

- The Laboratory researched state-of-the-art fabrication equipment that will improve quality, reduce cycle time and cost, and enable cutting-edge design solutions. Implementation of a three-year strategy has begun to bring these new capabilities into the Laboratory. These investments enable significant new capabilities in printed circuit board assembly, precision machining, rapid prototyping, and inspection.

- Work will continue on diverse hardware projects: integrating the HUSIR antenna, finalizing the LLCD design and initiating its fabrication, and developing rapid prototype systems. New efforts include spacecraft and aircraft payloads for laser communications and passive optical sensing, and systems for detecting IEDs.

- The Laboratory will focus on enhancing its mechanical design and printed circuit board layout capabilities to ensure that the most appropriate and advanced software tools are being used and that the Laboratory's design experts are best aligned to support Laboratory needs.

- Emphasis continues on improving engineering facilities, including advanced tools for mechanical fabrication and electronic assembly. The mechanical inspection facility will be completely refurbished. Because the large number of programs requiring clean-room assembly areas has been straining the infrastructure, new cleans rooms are under construction, and plans will be developed for specifying the capabilities needed in future new construction.

- The new analysis group will focus on performing insightful analysis to couple mission and design trade spaces, and provide design direction for all phases of a program in a timely way. The goal is to provide this capability to diverse classes of mechanical designs.

- Lincoln Laboratory will continue expanding its robotics programs, making use of the techniques and experience gained from the autonomous mapping project.

CYBER SECURITY

The Cyber Security mission conducts research, development, evaluation, and deployment of prototype components and systems designed to improve the security of computer networks, hosts, and applications. Lincoln Laboratory's cyber security efforts have grown from their roots in developing the first quantitative, repeatable, objective evaluations of computer network intrusion-detection systems to include assessment via analysis; modeling, simulation, emulation, and field testing; creation of survivable architectures; development of prototype components and systems consistent with these architectures; quantitative evaluation of these components and systems; and, where appropriate, deployment of these prototypes in experiments, exercises, and operations.

Kevin Carter and Tamara Yu use Lincoln Laboratory–developed visualization tools to explore and analyze the statistics of global cyber attacks launched against DoD mission-critical networks.

Principal 2010 Accomplishments

- The Laboratory developed and demonstrated components of a cyber survivable architecture in a combined ballistic missile defense/space situational awareness/cyber event. Cyber survivable systems are designed to ensure the ability of a system to continue providing mission utility while undergoing a cyber attack.

- Cyber situational awareness tools were developed to display worldwide malware activity; the tools have the ability to interactively drill down to discover cities and countries that permit or actively prevent the spread of malicious code. These tools have been installed into key national-level cyber-threat operations centers.

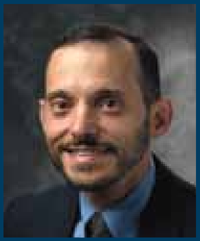
- Laboratory-developed approaches to secure communications among dynamic groups of participants in a tactical environment (unmanned aerial systems and ground stations in theater) were demonstrated and are being standardized for government and commercial use.

- A detailed assessment of the Air Force's widely deployed Host-Based Security System was conducted to permit the Air Force cyber acquisition community to better understand the performance and security implications of its procurement and policy decisions.

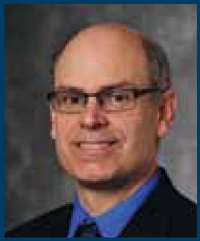
- The Lincoln Adaptable Real-time Information Assurance Testbed (LARIAT) cyber range software was restructured to include open interfaces among the system components. LARIAT is currently deployed at more than 80 DoD and contractor cyber ranges nationwide. This update will enable third-party capabilities to be easily integrated into the core system.

- The Laboratory developed and deployed prototype secure operating system modules for the next-generation Army communications-on-the-move, satellite-connected prototype network node. This system will provide the Army with the capability of secure communication from moving ground vehicles.

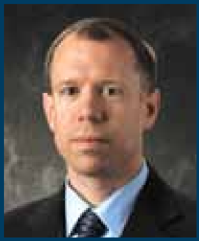
Leadership



Dr. Marc A. Zissman



Dr. Robert K. Cunningham



Mr. Joshua W. Haines

Mr. Lee M. Rossey

Adam Petcher, Mark Yeager, and Roger Khazan demonstrate a key management solution for unmanned aerial systems. The approach utilizes Laboratory-developed cryptographic protocols for dynamic group keying to secure the command and control channels while limiting receipt of the sensor broadcasts to groups of authorized users.

Lincoln Laboratory researchers developed hardware and software for an open network acceleration platform (NetFPGA) and a commercial field-programmable gate array development board to enable very low-observable instrumentation of cyber systems.

Future Outlook

- Lincoln Laboratory will continue work on the analysis of mission-critical systems to provide warfighters with insight into operating successfully in a contested cyber domain. This work supports traditional Laboratory mission areas, such as ballistic missile defense, space control, air vehicle survivability, and satellite communications.

- The Laboratory will develop an open architecture for tamper-resistant embedded systems. This effort will lead to a shift away from proprietary, classified anti-tamper approaches toward open systems that are still highly secure, but will reduce cost, enable reuse of components, and allow for rapid fielding.

- The overlap between the cyber domain and the physical domains (land, sea, air, space) will be more closely examined. The Laboratory seeks to help the DoD better understand how operating in one domain can have (often unintended) consequences in other domains.

- The Laboratory will continue to develop new technologies for large-scale cyber ranges, including novel methods to support low- or zero-artifact instrumentation and actuation.


LINCOLN LABORATORY

LABORATORY INVOLVEMENT

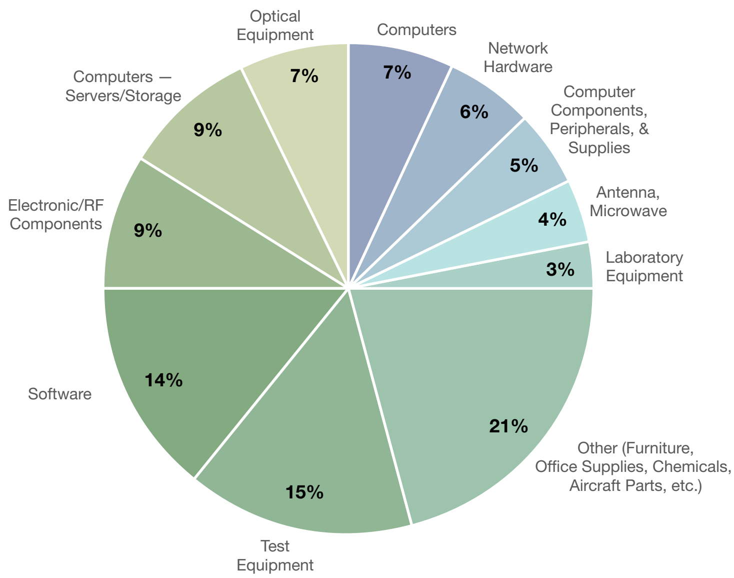
Technology Transfer and Economic Impact

Technology Transfer

A significant component of MIT Lincoln Laboratory's role as a federally funded research and development center is the transfer of Laboratory-developed technology to the government, industry (primarily government contractors), and academia. This transition of technology and information is accomplished through briefings and technical publications; deliveries of hardware, software, algorithms, or advanced architecture concepts; Small Business Technology Transfer (STTR) joint research partnerships with local businesses; Cooperative Research and Development Agreements (CRADAs), which are privately funded by businesses; and the licensing of MIT patents to companies.

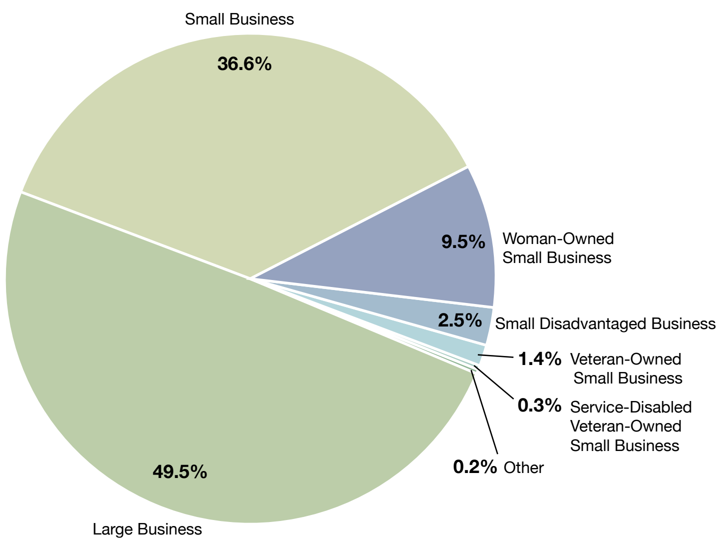
In 2010, Lincoln Laboratory undertook a broad variety of technology transfers to government contractors under the auspices of government sponsors:

- At the request of the Director of Defense Research and Engineering, the Laboratory began the transfer of fully depleted silicon-on-insulator (FDSOI) complementary metal-oxide semiconductor (CMOS) process technology to the Defense Microelectronics Activity (DMEA), which is responsible for ensuring the availability of critical electronics components to the military. The FDSOI CMOS technology will extend the range of semiconductor devices available through DMEA to include low-power devices, high-quality radio-frequency devices, and 3D integrated circuits.
- As a result of a DoD-sponsored transfer of the Laboratory's silicon and indium phosphide Geiger-mode avalanche photodiode technologies to U.S. industry, Boeing is now marketing a compact, 3D laser radar camera.
- Improved orthogonal-transfer charge-coupled devices have been delivered to the University of Hawaii for use in the focal plane of the second Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) optical system. Pan-STARRS is being developed to rapidly perform whole sky surveys to detect and catalog asteroids and comets that may present a threat to Earth.
- The National Center for Atmospheric Research funded a project that fuses Geostationary Operational Environmental Satellite visible and infrared imager data with the Tropical Rainfall Measurement Mission's low Earth-orbiting weather satellite radar



Total $116,792,041

Subcategories of commercial hardware and materials contracted to businesses



Total $344.5M

Percentage of awards to various categories of businesses

and lightning image data to determine the degree of aviation hazard presented by oceanic cumulonimbus cloud formations. These remote measurements confirm if the oceanic cumulonimbus cloud formations are active thunderstorms.

- Lincoln Laboratory is collaborating with the National Institutes of Health (NIH) New England Regional Center of Excellence at Harvard on broad-spectrum antiviral therapeutics. The NIH funds influenza mouse trials, conducted at the Division of Comparative Medicine on the MIT campus, and tests of the double-stranded, RNA-activated, caspace antiviral treatment against members of hemorrhagic fever virus families in cultured cells, conducted at the Laboratory.

Over the past year, Lincoln Laboratory was involved in five STTR projects, including projects on cryogenically cooled Yb:YAG lasers; a sparse aperture, electronically steered phased-array antenna; and the use of superconducting filters for electromagnetic interference suppression; and seven CRADAs, including geosynchronous communication satellite encounter analysis for Telesat Canada and Satmex; biosensor research and development for Innovative Biosensors; and semiconductor lithography research for Intel and Sematech.

Economic Impact

Lincoln Laboratory's research and development activities are a powerful economic engine for Massachusetts and enrich the economy of the region and the nation. Lincoln Laboratory contracts with both large and small businesses in the defense and commercial sectors, as well as with universities, for goods and services.

During the 12-month period ending in March 2010, the Laboratory issued subcontracts with a value that exceeded $340 million. In the past year, the Laboratory purchased more than $150 million in goods and services from New England companies, with approximately $130 million placed locally in Massachusetts. Small businesses—which supply construction, maintenance, fabrication, and professional technical services in addition to commercial equipment and material—have been primary beneficiaries of the Laboratory's outside procurement program. The Laboratory's Small Business Office is committed to an aggressive program designed to afford small business concerns the maximum opportunity to compete for purchase orders.

Recent U.S. Patents

20 October 2009 to 29 June 2010

Large-Aperture Focal Plane Shutter
Brian J. Julian and Anthony M. Smith
Date issued: 20 October 2009
U.S. Patent No.: 7,604,422

Contrast Enhancing Layers
Theodore H. Fedynyshyn
Date issued: 24 November 2009
U.S. Patent No.: 7,622,246

Wavelength Division and Polarization Division Multiple Access Free Space Optical Terminal Using a Single Aperture
Frederick G. Walther, Jeffrey M. Roth, William E. Keicher, and Alan E. DeCew
Date issued: 1 December 2009
U.S. Patent No.: 7,627,251

Multi-element Optical Detectors with Sub-wavelength Gaps
Eric A. Dauler, Andrew J. Kerman, Karl K. Berggren, Vikas Anant, and Joel K.W. Yang
Date issued: 29 December 2009
U.S. Patent No.: 7,638,751

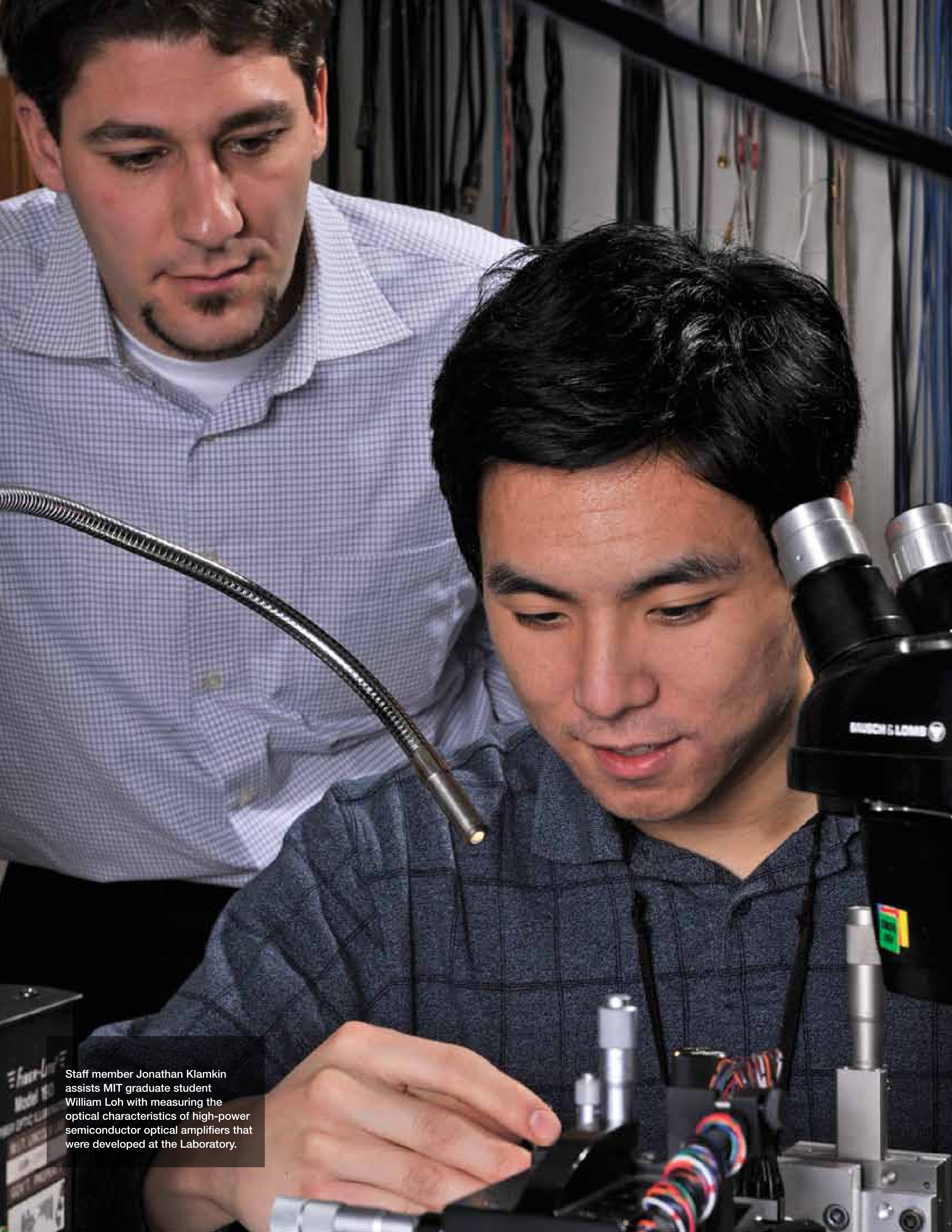
Method and System of Lithography Using Masks Having Gray-Tone Features
Brian M. Tyrrell and Michael Fritze
Date issued: 26 January 2010
U.S. Patent No.: 7,651,821

Method of Detecting Analyte Vaporized from Sample with Low-Power UV Radiation
Roderick R. Kunz
Date issued: 30 March 2010
U.S. Patent No.: 7,687,276

Acoustic Detection of Hidden Objects and Material Discontinuities
Robert Haupt and Ken Rolt
Date issued: 13 April 2010
U.S. Patent No.: 7,694,567

Immersion Fluid for Lithography
Theodore H. Fedynyshyn and Indira Pottebaum
Date issued: 29 June 2010
U.S. Patent No.: 7,745,102

As of June 2010, MIT had 691 U.S. patents, of which 336 had been licensed to industry for commercial applications, and 256 foreign patents derived from work at Lincoln Laboratory.

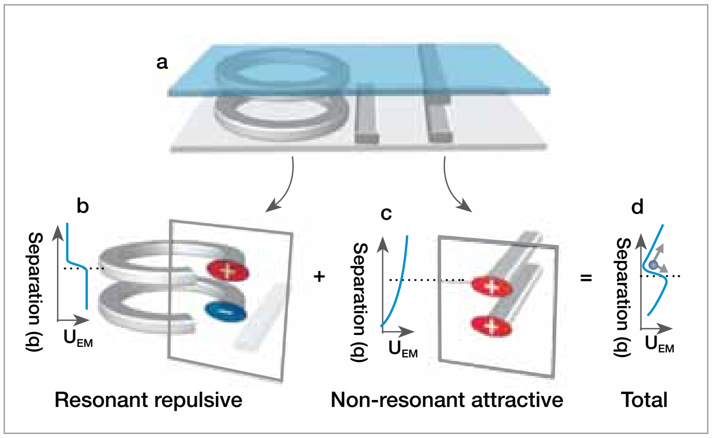


Staff member Jonathan Klamkin assists MIT graduate student William Loh with measuring the optical characteristics of high-power semiconductor optical amplifiers that were developed at the Laboratory.

MIT Campus and Lincoln Laboratory Collaborations

Integrated Photonics Initiative

The Integrated Photonics Initiative (IPI) is a multiyear, Lincoln Laboratory–funded collaboration between the Laboratory and the MIT campus to support the research of graduate students working on integrated photonic materials, devices, and subsystems. The IPI's objectives are to identify DoD mission areas that could benefit from integrated photonic technologies, to develop these technologies through graduate research, and to work to insert the technologies into advanced communication and sensor systems. Monthly meetings foster interaction between students, Laboratory staff, and faculty. The Laboratory's facilities and expertise in applied research benefit the students' thesis development. In the past year, three students focused on fabrication and test of integrated ultrafast all-optical switches, characterization of the noise and dynamic properties of high-power semiconductor optical amplifiers, development of low-noise semiconductor external-cavity lasers, and investigation of materials for use in integrated optical isolators. The students' accomplishments were highlighted at the Annual Meeting of the MIT Center for Integrated Photonic Systems.



A recent Advanced Concepts Committee project evaluated a microcavity that self-aligns resonance with incident laser frequency (shown above). The study proposed using optonanomechanical forces for novel optical devices.

Advanced Concepts Committee

The Lincoln Laboratory Advanced Concepts Committee (ACC) supports the development of innovative concepts that address important technical problems of national interest. The ACC provides programmatic support for new technology ideas that are typically high risk, but offer the potential to significantly impact national needs by enabling new systems or improving existing capabilities. Recent ACC-sponsored initiatives include researching sensors to image into obscured areas; developing fast secure network connection techniques; and assessing the use of the LLGrid to develop protection equipment models to mitigate traumatic brain injury. The ACC also sponsors a Defense Studies Seminar Series, which included the following in 2010: Sandy Weiner, MIT, "Pandemic Flu: Lessons Learned and Not Learned" and Austin Long, MIT, "U.S. Strategy in Afghanistan and Pakistan: Options and Possibilities."

Decision Modeling Research Initiative

The Decision Modeling Research Initiative (DMRI) is a collaboration between Laboratory technical staff members and MIT's Stochastic Systems Group (SSG). The DMRI provides a forum for sharing research and ideas in order to develop enhanced and scalable sensor fusion, inference, and decision-making algorithms and methodologies. Joint discussions have promoted the transfer of SSG-developed algorithms to Laboratory researchers and dialogue on challenges of interest to Laboratory programs.

MIT Undergraduate Research Opportunities Program

Under the MIT Undergraduate Research Opportunities Program, Lincoln Laboratory invites undergraduates to participate in onsite research projects. Students develop research plans, write proposals, perform experiments, analyze data, and present research results. The Laboratory typically hosts five students in the summer and three in the winter.

Technology Office Special Seminar Series

Technology Office seminars are key to continued interactions with campus. The Technology Office hosts technical seminars by MIT faculty, facilitating the opportunity for Laboratory technical staff to engage with leading-edge researchers from the MIT campus. Reciprocal fall seminars on campus provide a forum to extend Lincoln Laboratory's intellectual impact on campus. These talks give students and faculty an opportunity to hear about ongoing and emerging work at the Laboratory and at MIT. Topics of recent talks included human-robot interactions, optical biological control tools, black-hole event horizons, and a unifying theory of learning.

University Interactions and Student Programs

Lincoln Laboratory and Northeastern Seminar Schedule

Four Lincoln Laboratory technical presentations were hosted in 2009 by the Electrical and Computer Engineering Department at Northeastern University in the areas of embedded digital systems, information systems, and advanced sensor techniques. Four Northeastern University professors presented seminars on mobility of wireless sensor networks, nanoelectronics, and supercomputer application productivity and portability. This recently initiated seminar series has been successful in promoting strong collaborations and inspiring new ideas.

Lincoln Laboratory and Tufts University Seminars

Presentations by visiting professors from Tufts University are intended to further the collaboration between the university and the Laboratory. The three presentation topics covered remote homology detection, variational methods for image analysis, and geographic probabilistic routing. Speakers included the Associate Dean of Research and prominent professors from the Electrical and Computer Engineering Department and the Computer Science Department.

Student Programs

Lincoln Laboratory participates in a variety of programs through which students gain research experience or investigate careers in engineering, technology, science, or math. Under some programs, students fulfill an academic requirement, while other programs support thesis work at specific universities or offer paid internships at the Laboratory.

Summer Research Program

Lincoln Laboratory offers approximately 100 students hands-on experience in communications systems, sensor and radar data analysis, digital signal processing, laser and electro-optical systems, solid-state electronics, software engineering, and scientific programming. Program participants contribute to projects and gain experience that complements their courses of study.

University Cooperative Education Students

Technical groups at Lincoln Laboratory employ students from MIT, Northeastern University, and other colleges as co-ops working full time with mentors during the summer or work/study semesters and

Cadets from the New Jersey Institute of Technology toured Lincoln Laboratory's Flight and Antenna Test Facility.

part time during academic terms. Co-ops build prototypes, help solve problems, assist in research activities, and test applications in the field.

Graduate Fellowship Program

Lincoln Laboratory offers limited graduate fellowships to science and engineering students pursuing MS or PhD degrees at 11 partner universities. The fellowship program awards funds to support a fellow's stipend, supplement a graduate assistantship, or subsidize other direct research expenses during the final phases of students' thesis research.

MIT VI-A Master of Engineering Thesis Program

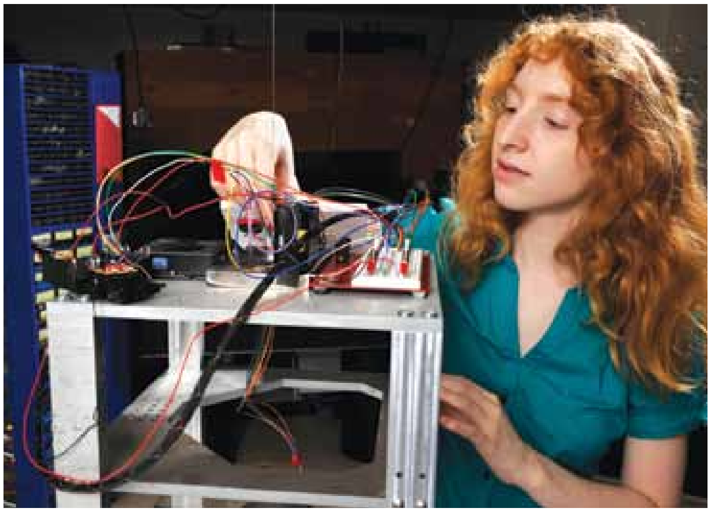
Lincoln Laboratory is an industry partner of MIT's Department of Electrical Engineering and Computer Science VI-A Master of Engineering (MEng) Thesis Program, matching motivated graduate students with mentors. Students in a VI-A internship acquire experience in testing, design, development, research, programming, and project planning. The students are then supported as research assistants while they complete their Lincoln Laboratory–specific MEng theses.

WPI Major Qualifying Project Program

Lincoln Laboratory collaborates with Worcester Polytechnic Institute (WPI) in its Major Qualifying Project (MQP) program, which requires students to complete an undergraduate project equivalent to a senior thesis. The MQP demonstrates the application of skills, methods, and knowledge to the solution of a problem representative of the type encountered in industry.

Undergraduate Diversity Awards

Lincoln Laboratory established the Undergraduate Diversity Awards to expand opportunities for women and minorities pursuing bachelor's degrees in engineering and science at 11 participating colleges. The award, as determined by the recipient's college, is typically in the form of tuition assistance, support for technical paper presentations, or funds for independent research projects.



(Top) Summer student Jillian James designed and built a rotating satellite test fixture including control boards and a reaction wheel during her summer research in the Space Systems Analysis Group.

(Middle) Summer student Arie Vilders conducted environmental, thermal, and acceptance tests on two Missile Alternative Range Target Instrument systems while in the Aerospace Engineering Group.

(Right) MIT VI-A student Karen Chu incorporated pitch features in automatic recognition of Mandarin Chinese in her work with the Communication Systems and Cyber Security Division.

Educational and Community Outreach

Educational Outreach

Science on Saturday

This program features onsite science demonstrations by Lincoln Laboratory technical staff. More than 3500 local K–12 students, their parents, and teachers have enjoyed demonstrations on rockets, robotics, asteroids, archaeology, optics and lasers, and polymers over the course of the school year.

Classroom Presentations

Dr. Todd Rider coordinates a program that sends technical staff members to local schools, giving presentations to students in grades K–12. More than 7000 students now enjoy presentations on topics such as cryogenics, electronic circuits, paleontology, biotechnology, and astrophysics each year.

AFCEA International Program

Lincoln Laboratory participates in the Armed Forces Communications and Electronics Association (AFCEA) International Program, which facilitates research internships for high-school seniors. Lincoln Laboratory employed three AFCEA students as research assistants this year and provided a tour of Laboratory facilities to all area AFCEA students.

Robotics Outreach at Lincoln Laboratory

Robotics Outreach at Lincoln Laboratory (ROLL) seeks to foster a sense of excitement that might drive students toward math, science, and engineering by engaging them in robotics workshops.

ROLL hosted two Weekend Robotics Workshops—two-day, full-immersion programs in which students learned and tested robotic programming sequences. Smaller robotic workshops were offered to younger robotics teams to practice robotic programming.

ROLL manned a booth at the Cambridge Science Festival, helping children learn engineering through hands-on building and programming of Lego robots. Younger children learned about system engineering by acting as robots and receiving/performing commands.

In 2009, ROLL recruited technical staff as judges for the Massachusetts State Science and Engineering Fair and Lexington High School's Science and Engineering Fair. Eric Austin, Anthony Filip, Robert Legge, Brian Shucker, Joseph Stewart, and Grant Stokes served as judges. In 2010, the Laboratory became a bronze donor to the State Science Fair and supplied nine judges: Shourov Chatterji, Jessica Deniger, Phillip Evans, Caroline Lamb, Todd Rider, Neal Spellmeyer, Zack Weber, Alexandra Wright, and Jung Yoon.

(Above left) Science on Saturday program; (above right) SEED Academy students listened to the Laboratory's David Freeman as he explained why he chose a career in engineering.

Outreach by the Numbers

10
community giving programs

19
K–12 STEM programs

100+
Lincoln Laboratory scientists and engineers working with students

5,250
volunteer hours a year in STEM programs

10,000
students participated in Lincoln Laboratory STEM programs

Leadership Initiatives for Teaching and Technology

The Leadership Initiatives for Teaching and Technology (LIFT²) program provides high-school teachers with internships in a technical field to help them relate classroom curricula to relevant workplace applications. In 2009, the Laboratory hosted one internship in the Chemical and Biological Defense Systems Group to develop an algorithm to derive room dimensions from simple range-finder data, and a second internship in the Active Optical Systems Group to optimize flight mission profiles for an airborne laser radar system.

MIT Department of Engineering Outreach Program

In 2010, Lincoln Laboratory and MIT's Department of Engineering's Office of Engineering Outreach Program are partnering in educational outreach for K–12 students in four MIT educational outreach programs.

Minority Introduction to Engineering and Science (MITES) Program

Lincoln Laboratory sponsored two students in a six-week residential summer program for the top high-school students in the nation. This program stresses the value of pursuing technical degrees and develops the skills necessary for success in technical fields. The MITES Program students attended presentations given by technical staff members Pablo Hopman, Lisa Basile, and Bryan Reid about careers in science and engineering. The students also received tours of Laboratory facilities.

Saturday Engineering Enrichment and Discovery (SEED) Academy

The SEED Academy features seven semesters of technical career exploration for promising but underserved high-school students in Boston and Cambridge. Lincoln Laboratory sponsored an aeronautics course and presentations at MIT by Laboratory technical staff members Aimee D'Onofrio and David Freeman about science and engineering topics and career choices.

Science, Technology, Engineering, and Mathematics (STEM) Program

The STEM Program is an academic enrichment program for middle-school students who want to get ahead in math and science. The participants develop mathematical thinking and problem-solving abilities in an attempt to increase the number of local students in technical careers. Seventy STEM students enjoyed a hands-on robotics demonstration, received a tour of Laboratory facilities, and heard presentations by technical staff members Rodolfo Cuevas and Shelley Scruggs about careers in math and science.

ROBOTICS OUTREACH AT LINCOLN LABORATORY

In its third year, Robotics Outreach at Lincoln Laboratory (ROLL) continued to provide successful experiences for young people. ROLL doubled the number of teams sponsored for the FIRST (For Inspiration and Recognition of Science and Technology) robotic competitions—eight groups ranging from 9- to 18-year-olds, mentored by volunteers at weekly sessions to program robots to complete an obstacle course. This year, ROLL forged a collaboration with Arlington High School by mentoring a rookie team for the robotics competition. With the help of Laboratory volunteers, the Arlington team received guidance on designing, building, and programming their robot for competition.

Two of the Lincoln Laboratory teams won awards in statewide competitions. The RoboBeavers received the Leonardo da Vinci Award for out-of-box thinking and unique creative robot design, and the LLAMAs won the Champion's Award for technical performance, teamwork, respect, and gracious professionalism. MITiBots, Lincoln Laboratory's returning team of 15- to 18-year-olds, won a lottery placement to compete at the 2010 World Championships in Atlanta in April, where they placed 13th out of 50 teams at the Finals. Lincoln Laboratory teams were among the 45,200 high-school students from 12 countries who participated in FIRST competitions this year.

(Above) A team of 11-year-olds called the RoboBeavers mastered advanced features and practiced coding multiple robots. This ROLL-sponsored team designed their robot to be reliable and perform with repeatable results.

Laboratory staff challenged participants in the MIT Science of Baseball Program to a softball game after the students toured the Laboratory.

Laboratory employees and Hanscom personnel participated in the 5K Fun Run hosted by the MIT Lincoln Laboratory Fitness Center. The event supported a local veteran's hospital.

Lincoln Laboratory employees walked a 3.5 mile loop to raise money for the Alzheimer's Association.

MIT Science of Baseball Program (MSBP)

This summer program for eighth-grade boys from Boston and Cambridge features an academic and athletic curriculum that channels students' enthusiasm for baseball into an excitement for the math and science behind the game. Lincoln Laboratory sponsored a local student, provided tours of the Flight and Antenna Test Facility, and hosted a "students versus scientists" softball game at Hanscom Air Force Base.

Community Service and Giving

Multiple Sclerosis Hike and Bike Event

Laboratory staff participate annually in the National Multiple Sclerosis Society's "Hike and Bike the Berkshires" event. This year, Lincoln Laboratory hiking and cycling teams raised more than $15,000, making Lincoln Laboratory the second leading fund-raiser in the event.

Used-Book Drive and Sale

In coordination with the MIT Community Giving Fund, Lincoln Laboratory raised over $1140 at an April used-book drive and sale to support community services.

Support Our Troops Drive

Lincoln Laboratory runs an ongoing campaign of support for deployed U.S. troops. Donations of food, toiletries, books, and games are collected daily, boxed by volunteers, and mailed weekly. Last year, Support Our Troops sent 215 care packages to 37 Army, Navy, Air Force, and Marine troops in Iraq and Afghanistan.

Memory Walk

The past year marked the beginning of LLCO support of the Alzheimer's Association Memory Walk. In its rookie year, the Lincoln Laboratory team raised more than $12,300 for the Alzheimer's Association, providing programs and services for the 140,000 Massachusetts and New Hampshire residents with Alzheimer's disease.

Coat Drive

In coordination with Anton's Coats for Kids program, Lincoln Laboratory donated over 500 warm winter coats that were cleaned and distributed to needy men, women, and children.

Sock Drive

New in 2009 was LLCO participation in the "Hannah's Socks" program, a charity named after a young Ohio girl who offered her own socks to a homeless man, and 1,930 pairs of socks were donated for the homeless, victims of domestic violence, and underprivileged children.

Diversity and Inclusion

Lincoln Laboratory recognizes that diversity in experience and culture promotes innovative thought and excellence. Recent initiatives are fostering an inclusive workplace that leverages and supports the talents and perspectives of its staff.

Lincoln Laboratory New Employees Network

The Lincoln Laboratory New Employees Network (LLNEN) helps new employees transition to the Laboratory and the region. Members serve as resources for one another, providing information and insights on the Laboratory, local services, and professional development activities. LLNEN's monthly social events, such as a bowling luncheon or a ski trip, typically attract 40 people. Outreach activities for 2010 include participating in the Laboratory's Science on Saturday program, developing a physics activity in conjunction with the MIT Science of Baseball Program for eighth graders, and working with Habitat for Humanity in Bedford, Massachusetts.

Lincoln Laboratory Technical Women's Network

The mission of the Technical Women's Network (LLTWN) is to promote the recruitment, retention, and achievement of women technical staff at Lincoln Laboratory. The group provides professional development opportunities, sponsors a mentoring program, encourages participation in the Laboratory's recruiting efforts, and promotes educational outreach activities to interest young women in science, math, and engineering.

LLTWN FY2010 highlights

30 March 2010

"Recognizing the Best and the Brightest: Gender and Race in Research," a presentation by Prof. Sally Laslanger, MIT, Director of the MIT Women's and Gender Studies Program.

29 January 2010

Technical briefings on current Laboratory initiatives in communications technology.

14 December 2009

Discussion on conflict resolution with Dr. Joanne Kamens, Director of Research Collaborations, RXi Pharmaceuticals, and member of the board of directors of Women Entrepreneurs in Science and Technology.

LLNEN members toured the RF Systems Test Facility and the Flight Facility that houses the Laboratory's airborne test bed. Here Alan Fenn of the Advanced RF Sensing and Exploitation Group is showing the group the instrumentation on an unmanned aerial vehicle.

Geeth Chettiar of Lockheed Martin discussed the business imperatives that drive increased focus on diversity and inclusion in the workplace.

Diversity Congress, October 2009

The Diversity Congress discussed ways to create a stronger culture of diversity and inclusion within Lincoln Laboratory. Management from across the Laboratory learned about Lincoln Laboratory's efforts in building such a culture. Recruiting at a broader range of colleges and universities, new programs in mentoring, a more comprehensive new employee orientation, and flexible work options are contributing to the hiring and retaining of a more diverse workforce.

Speakers included Eric Evans, Director, Lincoln Laboratory; Bill Kindred, Manager of Diversity and Inclusion, Lincoln Laboratory; Alison Alden, Vice President of Human Resources, MIT; and Geeth Chettiar, Vice President for Diversity and Equal Opportunity Programs, Lockheed Martin Corporation.

Workshops and Technical Education

Workshops and Seminars

The 2010 slate of conferences, workshops, and seminars shows the breadth of research that Lincoln Laboratory shares with the technical and defense communities. The workshops address technology developments in the Laboratory's long-standing mission areas, such as air and ballistic missile defense, and in its newer areas of research, such as homeland protection. Many of the workshops bring in guest speakers from the defense community, industry, and academia to add their unique perspectives on the application of advanced technology to their fields. These events provide valuable exchanges of ideas and insights into directions for future research.

High Performance Embedded Computing Workshop: 22–23 September 2009

Intelligence, Surveillance, and Reconnaissance Systems and Technology Workshop: 17–19 November 2009

Homeland Protection/Chem-Bio Defense Systems Workshop: 16–18 March 2010

Defense Technology Seminar (DTS): 21–26 March 2010

Space Control Conference: 4–6 May 2010

Air Vehicle Survivability Workshop: 11–13 May 2010

Ballistic Missile Defense Joint Advisory Committee Seminar: 18–20 May 2010

Cyber and Netcentric Workshop: 13–14 July 2010

Technical Education

Lincoln Laboratory offers educational opportunities for its staff and for user communities with which the Laboratory interacts. Courses for employees are geared to broadening technical knowledge and skills, and to acquainting new staff members with the Laboratory's advanced technology and technical themes. Courses for invited military officers and Department of Defense civilians are designed to further their understanding of current research and the systems developed at the Laboratory, and are part of the Laboratory's mission to extend scientific knowledge.

Educational Opportunities for Laboratory Staff

Graduate Education Programs

Lincoln Scholars Program: In the past year, one staff member earned a doctorate and eleven earned master's degrees through

This year marked the fourteenth annual Defense Technology Seminar at Lincoln Laboratory. Attendees included military officers and Department of Defense civilians. The seminar focused on the application of advanced electronics technology to critical surface, air, and space military challenges. A number of distinguished guest speakers offered insights on current national security issues.

Lincoln Scholars Kimberlee Chang and Seth Hunter use the Laboratory's simulation capabilities to perform real-time testing of "sidecar" processors.

the Lincoln Scholars Program, a competitive program for which technical staff are eligible to apply and under which participants are funded by the Laboratory for full-time pursuit of an advanced degree at MIT or another local university. Lincoln Scholars continue to contribute to the Laboratory under terms arranged with the Graduate Education Committee and to work at the Laboratory during summer breaks.

Distance Learning: Staff members may apply to pursue either of two specialized master's degrees through distance learning programs—the Master of Science in Information Technology–Software Engineering offered by Carnegie Mellon University and the Master of Professional Studies in Information Sciences offered by Pennsylvania State University College of Information Sciences and Technology. The Graduate Education Committee coordinates these programs with the respective universities. The programs allow technical staff to gain advanced degrees while continuing to work full time at the Laboratory. In 2009, the first seven participants completed Carnegie Mellon master's degrees. Currently, four people are enrolled in the Carnegie Mellon program and three in the Penn State program.

In-House Technical Education Courses

Semester-Length Courses: Lincoln Laboratory offers semester-length onsite courses taught by senior technical staff members or guest lecturers. The courses, which typically run 12 to 16 weeks, encourage technical versatility by extending participants' knowledge in new disciplines. Courses offered in FY10 were Linear Algebra, Understanding and Using Digital Signal Processing, Network Coding, and Introduction to Radar Systems (Part 1).

Build Anything: The Engineering Division offered a six-month series of 11 sessions on the Laboratory's advanced fabrication capabilities and facilities. The sessions, which included laboratory demonstrations, covered mechanical fabrication and design; electronic components and electronic assembly; assembly, integration, and testing of systems; and rapid prototyping. The goal of this new course was to help system designers by acquainting them with the Laboratory's capabilities in building components and complex hardware.

Education for Military Officers and DoD Civilians

Networking and Communications Course (NCC): *10–13 May 2010*
Through lectures, demonstrations, and tours, the NCC provides both fundamental and advanced concepts of networks and communications. The current focus is on cyber and net-centric operations.

Introduction to Radar Systems Course: *15–17 June 2010*
This course, a version of which is offered in-house to staff and online via the Laboratory's web site, has been developed to provide an understanding of radar system concepts and technologies to individuals involved in radar system development, acquisition, and related fields.

Anti-tamper Policy, Technology, and Application Course:
This monthly course provides a broad overview of the role of anti-tamper (AT) technology in DoD systems. It describes the DoD policy on AT, the engineering processes used to develop AT, and the hardware and software techniques used to implement AT.

Courses at the Naval War College: In collaboration with faculty from the Fletcher School at Tufts University, Lincoln Laboratory technical staff present courses at the Naval War College in Newport, Rhode Island. Each semester, Laboratory staff offer one elective to officers from all branches of the military and the Coast Guard. In fall 2009, Laboratory staff delivered a course in ballistic missile defense; in the 2009/2010 winter term, Laboratory engineers lectured on net-centric and cyber operations; and in spring 2010, the Laboratory offered a seminar course on space technology and policy.

Awards and Recognition

Appointments to Defense Science Board

William P. Delaney (left) and ***Dr. Eric D. Evans*** (right) appointed as Senior Fellow and Member, respectively, of the Defense Science Board.

MIT Lincoln Laboratory Career Achievement Award

Roger W. Sudbury (see profile, page 51), in recognition of his commitment and technical contributions to the Massachusetts Institute of Technology and MIT Lincoln Laboratory, and for his exceptional service to the nation.

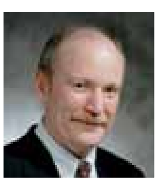
2010 Distinguished Service Award of the IEEE Microwave Theory and Techniques Society

Roger W. Sudbury, for outstanding service for the benefit and advancement of the IEEE Microwave Theory and Techniques Society.

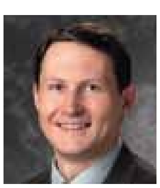
Department of Defense Outstanding Public Service Award

Walter E. Morrow, Director Emeritus, for exceptional contributions to the Department of Defense as a Member and Senior Fellow of the Defense Science Board, serving from January 1987 to September 2009.

2010 IEEE Fellows



Dr. Douglas A. Reynolds (left), for contributions to Gaussian-mixture-model techniques for automatic speaker recognition. ***Dr. Grant H. Stokes*** (right), for leadership in the development and implementation of advanced space search systems.



Appointment to Air Force Scientific Advisory Board

Dr. J. Scott Stadler, appointed as Member of the Air Force Scientific Advisory Board, which helps determine the research and development policy of the U.S. Air Force.

U.S. Air Force Civilian Service Awards

Dr. Hsiao-hua K. Burke received the Meritorious Civilian Service Award, and ***Dr. Robert T-I. Shin*** received the Exemplary Civilian Service Award, in recognition of their service on the Air Force Scientific Advisory Board.

2010 AFCEA Meritorious Award for Engineering

Dr. Thomas G. Macdonald, for contributions to the command, control, communications, computers, and intelligence (C4I) community and for a strong commitment to the goals of the Armed Forces Communications and Electronics Association (AFCEA).

Missile Defense Agency Technology Achievement Awards

Dr. Keh-Ping Dunn, Dr. Donald S. Coe, David L. Immerman, Christopher B. Johnson, Dr. Daniel O'Connor, and ***Dr. Paul Temple,*** for their work on the Theater Critical Measurements Program, which has "provided the ballistic missile defense community with a wealth of data and capability demonstrations." ***Dr. R. Louis Bellaire,*** for his work on the Operation Burnt Frost team, which successfully intercepted and destroyed a U.S. satellite that had veered out of orbit.

2010 Most Promising Engineer Award

Dr. Shakti K. Davis, named Most Promising Engineer or Scientist for 2010 at the U.S. Black Engineer of the Year Award Conference, for significant potential for technical contributions.

IEEE Best Paper Award

Best Paper Award at the 2009 IEEE International 3D Systems Conference for "Wafer-Scale 3D Integration of InGaAs Image Sensors with Si Readout Circuits," coauthored by ***Dr. Robert Berger***, ***Vladimir Bolkhovsky***, ***Dr. David C. Chapman***, ***Dr. Chang-Lee Chen***, ***Dr. Joseph P. Donnelly***, ***WeiLin Hu***, ***Dr. Craig L. Keast***, ***Jeffrey M. Knecht***, ***Leonard J. Mahoney***, ***Douglas Oakley***, ***Dr. David C. Shaver***, ***Antonio M. Soares***, ***Dr. Vyshnavi Suntharalingam***, ***Bruce D. Wheeler***, and ***Donna-Ruth Yost***.

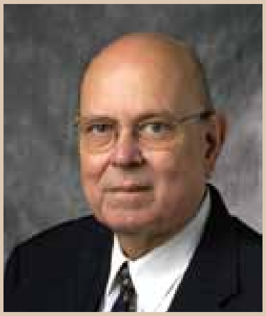
National Intelligence Meritorious Unit Citation

Dr. Mohamed D. Abouzahra, ***Gerald C. Augeri***, ***Dr. Eric J. Austin***, ***Dr. Jeffrey S. Herd***, ***Dr. Benny J. Sheeks***, ***Dr. Dieter Willner***, and ***Alexandra Wright***, recognized for their distinguished accomplishments on the Ballistic Missile Technical Collection Integrated Product Team, which received the citation for exceptional performance from the Office of the Director of National Intelligence.

ROGER W. SUDBURY

(1938–2010)

41 Years of Dedicated Service



Roger W. Sudbury was the former Executive Officer at MIT Lincoln Laboratory and served on the Director's staff. During his tenure at Lincoln Laboratory, he served as Assistant and then Associate Group Leader in the Systems Engineering Group and later the Experimental Systems Group. He led the development of high-frequency solid-state components for active-element phased-array radars, involving the design, development, and fabrication of devices and circuits for microwave transmit/receive modules. While leading the development of GaAs monolithic circuits at the Laboratory, he served as advisor to the government on GaAs multichip transceiver module development. He also served as Associate Manager of Lincoln Laboratory's Kiernan Reentry Measurements Site in the Marshall Islands, Kwajalein Atoll, where he was involved in the operation and management of radar and optical data collection experiments. He was also involved in the fielding and operation of Cobra Eye, an airborne infrared data-collection platform.

For many years, Roger served on the International Microwave Symposium (IMS) Technical Program Committee and three IMS Steering Committees, and was instrumental in the establishment of the Microwave- and Millimeter-Wave Monolithic Circuits Symposium. For the 1991 IMS in Boston, he edited a reissue of *Five Years at the Radiation Laboratory*. He served on the Microwave Theory and Techniques (MTT) Society AdCom and as MTT Society President in 2000. He also served on the Steering Committee of the IEEE International Symposium on Phased-Array Systems and Technology.

A Life Fellow of the IEEE, Roger served the IEEE in many capacities. He was a member of the IEEE Technical Activities Board and its Strategic Planning and Review Committee. He served as chair of the Conference Publications Committee, as Technical Activities Board liaison to the Regional Activities Board, and as vice chair of the IEEE Membership Development Committee. He served as chair of the Continuing Professional Education Committee and on the IEEE Educational Activities Board. A Past President of the IEEE MTT Society, he served as the MTT Awards Committee Chair and on the IEEE Awards Board Presentation and Publicity Committee. He was also on the Steering Committee of the IEEE International Microwave Symposium and its Technical Program Committee. He served on the IEEE Board and chaired its Employee Benefits and Compensation Committee.

Roger was a member of Phi Kappa Phi, Sigma Xi, Tau Beta Pi, Eta Kappa Nu, and Phi Eta Sigma honor societies. He held a BEE with highest honors from the Georgia Institute of Technology and the SM and Engineer (EE) degrees from the Massachusetts Institute of Technology. While an instructor in the MIT Electrical Engineering Department, he received a TV Management Shares Teaching Award.

(From left) Roger, promoted to Captain in the U.S. Army, receives his Captain's bars from Lieutenant Colonel Heard while his wife, Margaret, congratulates him; while serving on Kwajalein, Roger visited remote sites; during the filming of the Nova special "Echoes of War," Roger joined MIT Radiation Laboratory developers of the Army's SCR-584 on the restored radar.

2010 IEEE Educational Activities Board Employer Professional Development Award

MIT Lincoln Laboratory received this award "for exemplary leadership in providing programs for its employees, IEEE members, and other professionals for continuing education and professional development."

2010 IEEE International Symposium on Network Computing and Applications Best Paper Award

Dr. Roger I. Khazan, ***Benjamin W. Fuller***, ***Joseph A. Cooley***, ***Galen E. Pickard***, and ***Daniil M. Utin*** of the Cyber Systems and Technology Group, for the paper "ASE: Authenticated Statement Exchange."

Appointment to Information Science and Technology Panel

Nadya T. Bliss, appointed to the Defense Advanced Research Projects Agency (DARPA) Information Science and Technology Panel, which provides independent assessments of advanced information sciences and technologies.

2009 MIT Lincoln Laboratory Best Paper Award

Dr. Mykel J. Kochenderfer, ***Matthew W.M. Edwards***, ***Leo P. Espindle***, ***Dr. James K. Kuchar***, and ***J. Daniel Griffith*** for their paper "Airspace Encounter Models for Estimating Collision Risk," published in the *AIAA Journal of Guidance, Control, and Dynamics*, March–April 2010.

2010 MIT Excellence Awards

Unsung Hero Award: ***Shawn S. Daley*** (left)
Serving the Client Award: ***Michael R. Burke*** (right)
Fostering Diversity and Inclusion Award: Lincoln Laboratory Technical Women's Network Planning Committee (***Leslie Alger***, ***Emily Anesta***, ***Nadya Bliss***, ***Hsiao-hua Burke***, ***Eva Cardarelli***, ***Elizabeth Gustowt Champagne***, ***Melissa Choi***, ***Aimee D'Onofrio***, ***Ellen Johnson***, ***Karen Springford***, ***Vyshnavi Suntharalingam***, ***Anne Grover Vogel***, ***Christine Wang***, ***Michele Weatherwax***, ***Marilyn Wolfson***, and ***Tamara Yu***)

2009 MIT Lincoln Laboratory Technical Excellence Awards

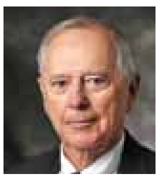
Dr. Tso Yee Fan (left), for innovation in the solid-state laser field by demonstrating the first diode-pumped Yb laser and by pioneering both the use of cryogenics for scaling solid-state lasers to high power with excellent efficiency and techniques for laser beam combining. ***Dr. David R. McElroy*** (right), for

The Lincoln Laboratory Technical Women's Network Planning Committee is seen here at the MIT Excellence Awards Ceremony with, in the back row from left to right, Eric D. Evans, Director, Lincoln Laboratory; Theresa M. Stone, Executive Vice President and Treasurer, MIT; L. Rafael Reif, Provost, MIT; and Kirk D. Kolenbrander, Vice President for Institute Affairs & Secretary of the Corporation, MIT. The LLTWN committee includes (front row left to right) Elizabeth Champagne, Christine Wang, Anne Vogel, Nadya Bliss, Tamara Yu, Emily Anesta; (middle row) Aimee D'Onofrio, Hsiao-hua Burke, Leslie Alger, Ellen Johnson, Vyshi Suntharalingam, Melissa Choi.

sustained contributions to the Department of Defense's MILSATCOM program, for critical contributions to the nation's communications priority as an innovator, architect, leader, and mentor of national stature, and for perfecting a method to transition Lincoln Laboratory technology to industry through the use of "gold standard" test instruments.

2009 MIT Lincoln Laboratory Best Invention Award

Dr. Eric A. Dauler and ***Dr. Andrew J. Kerman*** of MIT Lincoln Laboratory, and ***Prof. Karl Berggren***, ***Dr. Joel Yang***, and ***Dr. Vikas Anant*** of MIT for their invention "Multi-element Optical Detectors with Sub-wavelength Gaps," granted U.S. patent 7,638,751 in 2009.



2009 National Defense Industrial Association RADM Robert H. Gormley Award for Leadership

Alan D. Bernard, for exceptional and visionary contributions to aircraft combat survivability, the Armed Forces, and the nation.

IEEE Electron Devices Society 2009 George E. Smith Award

Dr. Jakub T. Kedzierski, ***Paul D. Healey***, ***Dr. Peter W. Wyatt***, ***Dr. Craig L. Keast***, ***Prof. Jing Kong*** (MIT), ***Pei-Lan Hsu*** (MIT VI-A student), and ***Alfonso Reina*** (MIT graduate student), for the paper "Graphene-on-Insulator Transistors Made Using C on Ni Chemical-Vapor Deposition," which was named the best paper published in 2009 in the *IEEE Electron Devices Letters*.

2010 Tech Citizenship Award for Community Outreach

Presented to MIT Lincoln Laboratory by Mass High Tech in recognition of the Laboratory's strong commitment to educational outreach and community service.

2010 Bay State Bike Week Mass Commuter Challenge Award

The Lincoln Laboratory team of 148 bicyclists earned a first place award in the 3000-to-5000-employee division in the Mass Commuter Challenge. The team also earned second place among all divisions.

2009 "Superior" Security Rating

To Lincoln Laboratory's collateral security program from the Commander of the 66th Security Forces Squadron at Hanscom Air Force Base.

Patriot Award

Shawn S. Daley, from the Massachusetts chapter of the National Committee for Employer Support of the Guard and Reserve, for coordinating support for a deployed Air Force reservist who is a member of the Laboratory's Security Services Department.

Young Innovator of the Year
Dr. Eric A. Dauler

Dr. Eric A. Dauler of the Laboratory's Optical Communications Technology Group has been selected as the 2010 *R&D Magazine* Young Innovator of the Year. This award is given annually by *R&D Magazine* to an innovator under the age of 31 from an academic, professional, or government organization. Winners are chosen for having demonstrated leadership in developing one or more innovative products within the prior year. Dr. Dauler was recognized for his contributions to the development of superconducting nanowire single-photon detectors and Geiger-mode avalanche photodiodes.

The Lincoln Laboratory nanowire photodetector arrays are the fastest, most sensitive single-photon detectors available. They operate in the ultraviolet, visible, and near-infrared spectral regions; provide the largest photon-counting rates; are relatively easy to fabricate; involve simple signal digital post-processing to obtain photon-number information; and detect light coming from a range of angles. These characteristics enable the arrays to advance what is now possible in optical communications. In the future, nanowire photodetector arrays will be used in laser-communications receivers on Earth and eventually in orbit as part of an optical deep-space communications network.

Geiger-mode avalanche photodiode two-dimensional arrays of ultrasensitive solid-state photodetectors enable three-dimensional laser radar imaging that has been used in mapping terrain, acquiring data for robotic vision, and imaging partially obscured objects.

R&D 100 Awards

Five Lincoln Laboratory technologies were named 2010 winners of R&D 100 Awards. These awards are given annually by *R&D Magazine*, an internationally respected journal providing news and technical articles to research scientists and engineers. Instituted in 1963, these awards recognize the 100 most technologically significant innovations introduced during the previous year. Recipients of R&D 100 Awards are chosen from hundreds of nominations by an independent panel of evaluators and the editors of *R&D Magazine*.

Previous R&D 100 award winners, which have included large companies, start-ups, universities, and government laboratories, span a broad range of applied research: fax machines, liquid crystal displays, antilock brakes, and the artificial retina.

At a ceremony in Orlando, Florida, Lincoln Laboratory technical staff members accepted 2010 R&D 100 Awards on behalf of their respective development teams. From left to right are Eric Shank, Michael Kelly, Kenneth Schultz, Simon Verghese, Merlin Green, Helen Kim, and Eric Dauler. Dr. Dauler was also named the *R&D 100 Magazine* Young Innovator of the Year.

Runway Status Lights

A system integrating data from airport surveillance sources to control in-pavement lights that directly alert pilots to potential runway incursions

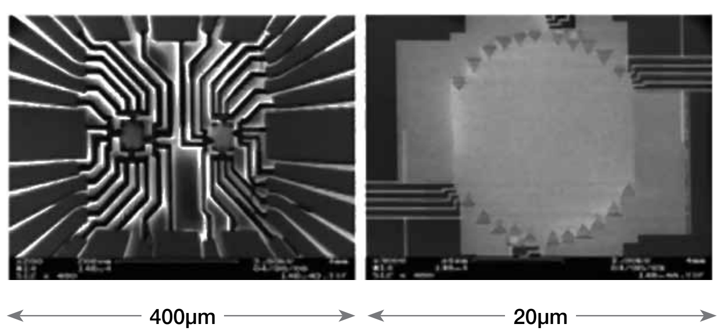
Developers: ***Dr. James R. Eggert, Dr. Eric M. Shank, Walter L. Brown, Dr. Richard W. Bush, Dr. Jeffrey L. Gertz, Daniel C. Herring, Leo Javits, Daniel A. Komisar, Maria Picardi Kuffner, Jessica E. Olszta***, and ***Harald Wilhelmsen***

(Left) Takeoff Hold Lights are shown implemented at the Los Angeles International Airport. These components of the Runway Status Lights system are placed at departure positions and indicate to pilots that it is unsafe to take off because a runway ahead is occupied by another aircraft.

Subwavelength-Separated Superconducting Nanowire Single-Photon Detector Array

A component in an optical detection system that enables broad-band single-photon detection with high efficiency and low noise at rates exceeding one billion photons per second

Developers: ***Dr. Eric A. Dauler*** and ***Dr. Andrew J. Kerman*** (Lincoln Laboratory), ***Prof. Karl K. Berggren*** (MIT), and ***Vikas Anant*** and ***Joel K.W. Yang*** (former MIT graduate students)

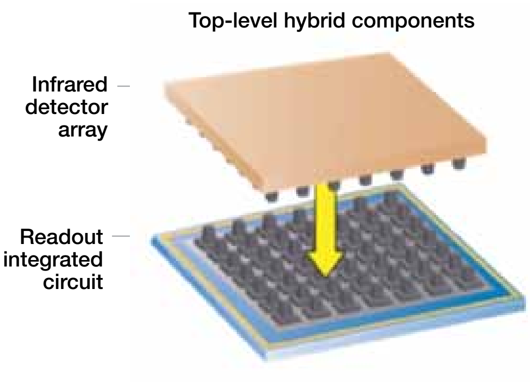


(Right) A scanning electron micrograph of two eight-element nanowire photodetector arrays fabricated at Lincoln Laboratory. (Far right) A magnified scanning electron micrograph of a single eight-element nanowire array.

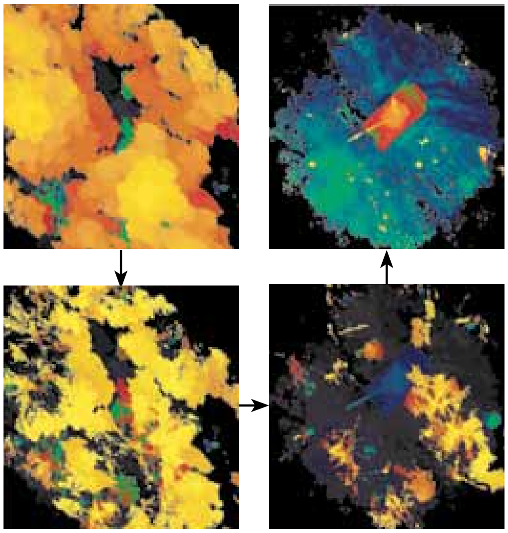
Digital-Pixel Focal-Plane Array

A complementary metal-oxide semiconductor readout integrated circuit for infrared imaging. Fast on-chip processing provides an extreme dynamic range from a minimally sized package (See p. 7 for images made possible by the digital focal-plane array.)

Developers: ***Dr. Michael W. Kelly***, ***Dr. Kenneth I. Schultz***, ***Lawrence M. Candell***, ***Dr. Daniel L. Mooney***, ***Curtis B. Colonero***, ***Dr. Robert Berger***, ***Brian M. Tyrrell***, ***James R. Wey***, ***Dr. Christopher L. David***, ***Stephanie Hsu***, ***Dr. Andrew M. Siegel, Joseph S. Costa, Eric J. Ringdahl, Dr. Matthew G. Brown, Justin J. Baker***, and ***Thomas D. Gardner***



(Right) The digital-pixel focal-plane array includes two top-level components: an infrared detector array and a readout integrated circuit (ROIC). Any commercial infrared detector may be used with the ROIC, which was designed at Lincoln Laboratory and manufactured at IBM.



Geiger-Mode Avalanche Photodiode Array

A two-dimensional array of ultrasensitive solid-state photodetectors, each of which can measure the arrival time of single photons

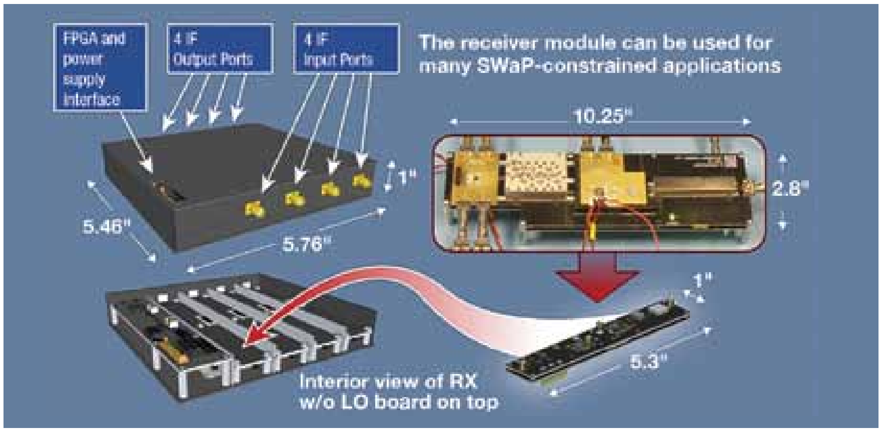
Developers: ***Dr. Simon Verghese***, ***Dr. Richard M. Marino***, ***Dr. Brian F. Aull***, ***Dr. Bernard B. Kosicki***, ***Dr. Robert K. Reich***, ***Bradley J. Felton***, ***Dr. David C. Shaver***, ***Andrew H. Loomis***, ***Douglas J. Young***, ***K. Alexander McIntosh***, ***David C. Chapman***, ***Joseph P. Donnelly***, ***Douglas C. Oakley***, ***Antonio Napoleone***, ***Dr. Erik K. Duerr***, ***Jonathan P. Frechette***, ***Joseph M. Mahan***, ***Joseph E. Funk***, ***Brian M. Tyrrell***, ***Dr. Pablo I. Hopman***, ***Dr. Eric A. Dauler***, ***Peter J. Grossmann***, and ***Leonard J. Mahoney***

(Left) A sequence of three-dimensional images obtained by using a laser radar camera that includes the Geiger-mode avalanche photodiode focal-plane array can be processed and registered to remove foliage that obscures objects of interest below. In the four images, color represents relative height. By changing the threshold and eliminating taller objects from view, the upper left image showing only treetops progresses to the upper right image revealing a tank and tree trunks.

Miniaturized Radio-Frequency Four-Channel Receiver

The smallest, least-power-demanding receiver that can detect frequencies over a six-octave range

Developers: ***Dr. Helen H. Kim***, ***Matthew D. Cross***, ***Merlin R. Green***, ***Daniel D. Santiago***, and ***Sabino Pietrangelo***



(Right) The four-channel miniaturized RF receiver occupies a single 6U VME card by replacing larger, low-yielding materials with silicon-germanium semiconductors. For comparison, a commercial two-channel RF receiver uses four 6U VME cards.

Organization

MIT Lincoln Laboratory Organizational Chart

Lincoln Laboratory

Eric D. Evans
Director

Marc D. Bernstein
Associate Director

Anthony P. Sharon
Assistant Director – Operations

Office of the Director

Steven R. Bussolari
Strategic Initiatives

John E. Kuconis
Executive Officer

Bernadette Johnson
Technology Officer

Bruce C. Bray
Interim Head
Safety and Mission Assurance

Service Departments

Contracting Services
Paul F. Conroy

Facility Services
Donald N. Holmes

Financial Services
Patricia O'Riordan

Human Resources
Brian S. Donahue

Information Services
Joseph M. Flynn
Chief Information Officer

Security Services
Shawn S. Daley
Chief Security Officer

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Andrew D. Gerber
Associate Head

Gerald C. Augeri
Assistant Head

Dennis J. Keane
Assistant Head

Communication Systems and Cyber Security

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Roy S. Bondurant
Associate Head

Stephan B. Rejto
Assistant Head

Marc A. Zissman
Assistant Head

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Head

Craig L. Keast
Associate Head

Charles A. Primmerman
Associate Head

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Assistant Head

Curtis W. Davis III
Assistant Head

James Ward
Assistant Head

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Israel Soibelman
Head

James M. Flavin
Assistant Head

Mark E. Weber
Assistant Head

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Head

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Assistant Head

Michael T. Languirand
Assistant Head

Aerospace

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Lawrence M. Candell
Assistant Head

Craig E. Perini
Assistant Head

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MIT

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Dr. Susan Hockfield, President

Office of the Provost
Dr. L. Rafael Reif, Provost

Dr. Claude R. Canizares, Vice President for Research and Associate Provost

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Annually reviews the Laboratory's proposal for programs to be undertaken in the subsequent fiscal year and five-year plan.

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Principal Deputy, Defense Research and Engineering

Dr. Regina E. Dugan
Director, Defense Advanced Research Projects Agency

Gen Bruce Carlson, USAF (Ret)
Director, National Reconnaissance Office

LTG Patrick J. O'Reilly
Director, Missile Defense Agency

Dr. Malcolm O'Neill
Assistant Secretary of the Army for Acquisition, Logistics and Technology

Mr. Sean J. Stackley
Assistant Secretary of the Navy for Research, Development and Acquisition

Mr. David Van Buren
Acting Assistant Secretary of the Air Force for Acquisition

Maj Gen Ellen Pawlikowski
Commander, Air Force Research Laboratory, Joint Advisory Committee Executive Group—Chair

MIT Lincoln Laboratory Advisory Board
Appointed by the MIT President and reports to the Provost. The Advisory Board meets twice a year to review the direction of Laboratory programs.

Mr. Kent Kresa, *Chairman*
Former Chairman and CEO of Northrop Grumman

Prof. Angela M. Belcher
Germeshausen Professor of Materials Science and Engineering, Massachusetts Institute of Technology

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President, Frost & Associates, Inc.; Former Deputy Commander, U.S. Space Command

Dr. Arthur Gelb
President, Four Sigma Corporation; Former Chairman and CEO of The Analytic Sciences Corporation

ADM Edmund P. Giambastiani Jr., USN (Ret)
Former Vice-Chairman of the Joint Chiefs of Staff

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Prof. Hans Mark
The University of Texas at Austin; Former Secretary of the Air Force; Former Deputy Administrator of NASA

Prof. Jeffrey H. Shapiro
Julius A. Stratton Professor of Electrical Engineering, Massachusetts Institute of Technology; Director, MIT Research Laboratory of Electronics

Mr. John P. Stenbit
Former Assistant Secretary of Defense (C3I); Former Executive Vice President, TRW

GEN Gordon R. Sullivan
President of the Association of the U.S. Army; Former Chief of Staff of the U.S. Army

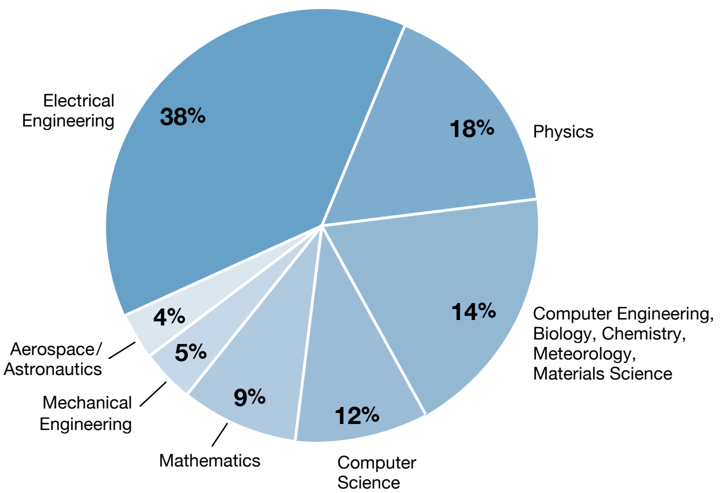
Staff and Laboratory Programs

Staff Technical Equivalents: 1,502
Support: 1047
Technical Support: 357
Subcontractors: 541

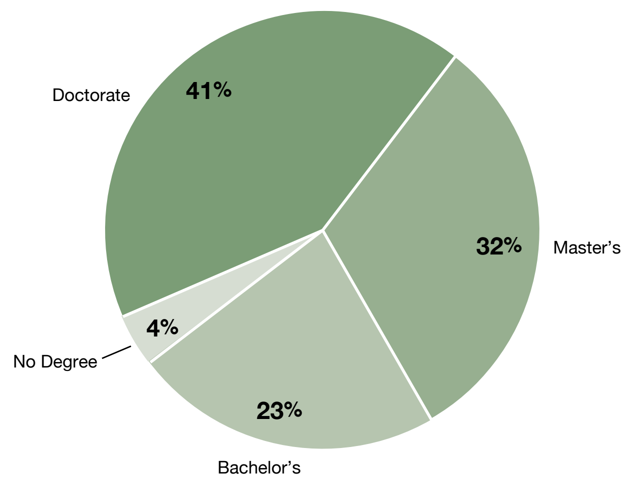
Total Employees: 3,447

Composition of Professional Staff

by Academic Discipline

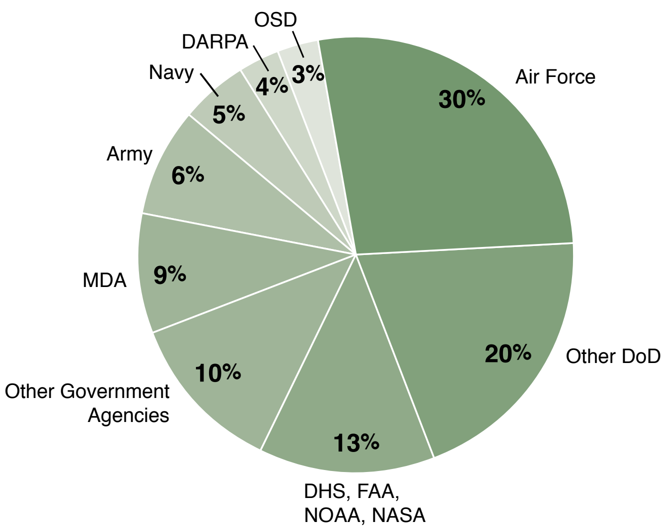


by Degree

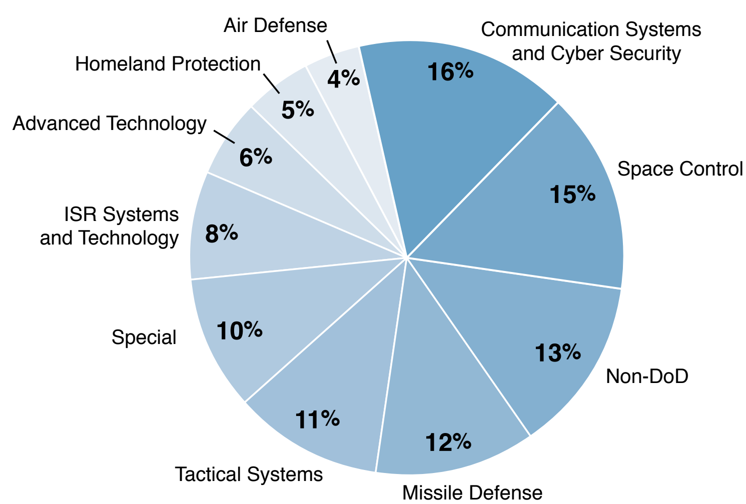


Breakdown of Laboratory Programs

by Sponsor

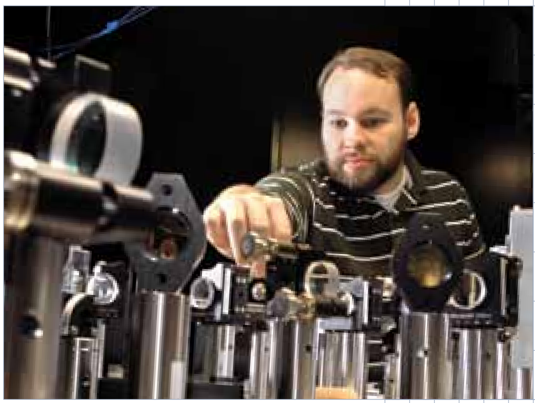


by Mission Area



Lincoln Space Surveillance Complex, Westford, Massachusetts

Reagan Test Site, Kwajalein Atoll, Marshall Islands



LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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TECHNOLOGY IN SUPPORT OF NATIONAL SECURITY